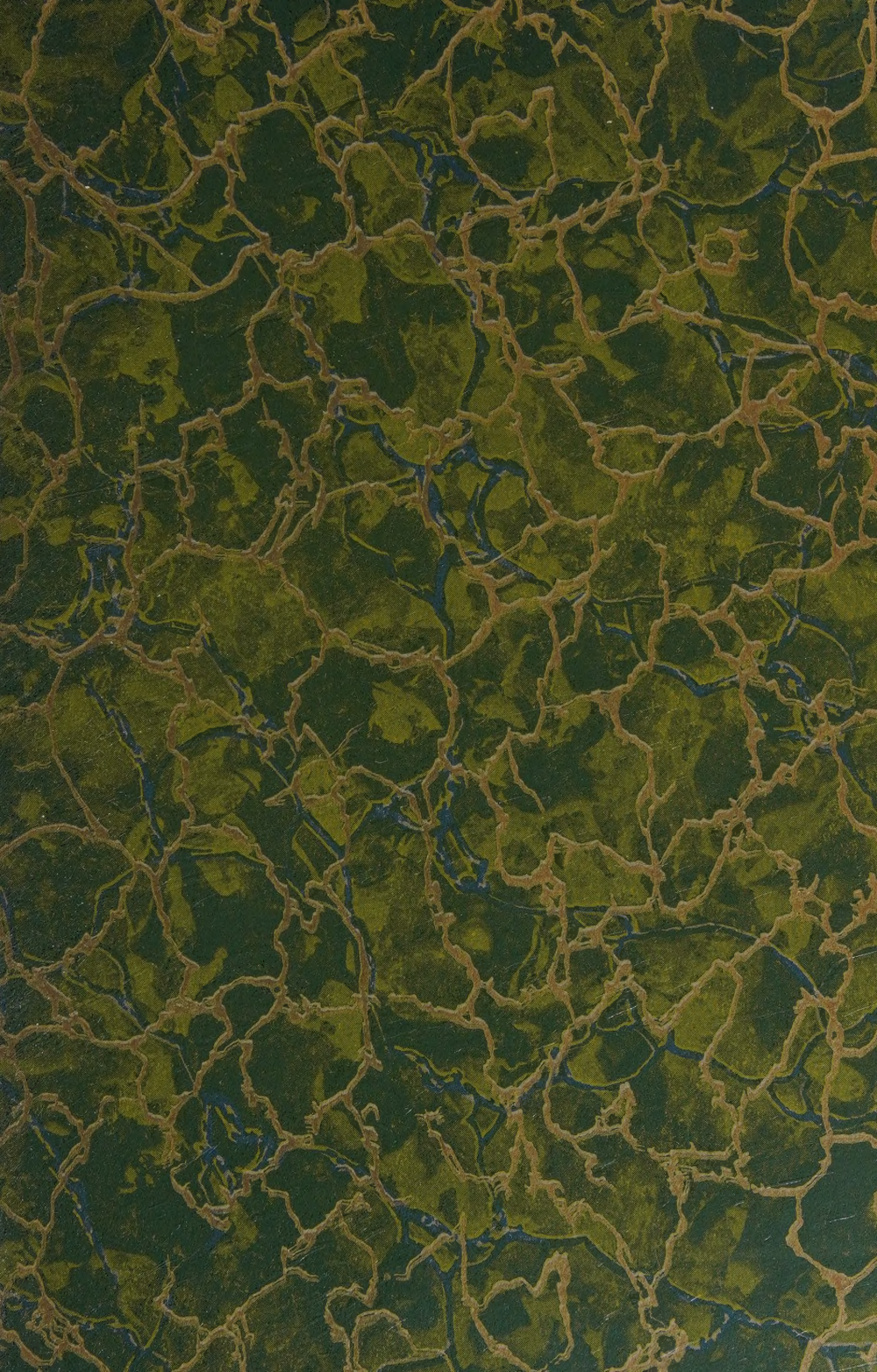

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Automobile Construction and Carbureters

201 ILLUSTRATIONS

By

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GASOLINE AUTOMOBILES
AUTOMOBILE ENGINE AUXILIARIES
AUTOMOBILE CARBURETERS
FORMS OF CARBURETERS
GASOLINE AUTOMOBILE ENGINES

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PREFACE

The volumes of the International Library of Technology are made up of Instruction Papers, or Sections, comprising the various courses of instruction for students of the International Correspondence Schools. The original manuscripts are prepared by persons thoroughly qualified both technically and by experience to write with authority, and in many cases they are regularly employed elsewhere in practical work as experts. The manuscripts are then carefully edited to make them suitable for correspondence instruction. The Instruction Papers are written clearly and in the simplest language possible, so as to make them readily understood by all students. Necessary technical expressions are clearly explained when introduced.

The great majority of our students wish to prepare themselves for advancement in their vocations or to qualify for more congenial occupations. Usually they are employed and able to devote only a few hours a day to study. Therefore every effort must be made to give them practical and accurate information in clear and concise form and to make this information include all of the essentials but none of the non-essentials. To make the text clear, illustrations are used freely. These illustrations are especially made by our own Illustrating Department in order to adapt them fully to the requirements of the text.

In the table of contents that immediately follows are given the titles of the Sections included in this volume, and under each title are listed the main topics discussed.

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GASOLINE AUTOMOBILES

GENERAL CHARACTERISTICS

INTRODUCTION

CLASSIFICATION OF MOTOR VEHICLES

1. In its broadest sense, the term *automobile* applies to any self-propelled vehicle, including even steam road rollers, the traction engines used in agricultural work, and locomotives. Custom, however, has narrowed the application of this term until it is now chiefly applied to the self-propelled vehicles used for the transportation, without payment therefor, of passengers for pleasure or for business purposes. When the same automobile is diverted from its original purpose to the carrying of passengers for a money consideration, it is then spoken of as a *livery automobile* or a *livery car*, or, in case the fare charged is very small, such as 5 or 10 cents, as a *jitney*, implying that it is for hire. The terms *motor car*, or *car* for short, and *motor vehicle* are used synonymously with the term automobile.

Motor vehicles devoted entirely to the carrying of freight are called *motor trucks, auto trucks, delivery cars, delivery wagons*, or *commercial vehicles*, the latter term being sufficiently broad to embrace them all as a class distinct from pleasure vehicles. Although automobiles are sometimes hired for touring purposes, motor vehicles for the transportation of passengers for hire in cities, exclusive of jitneys, for which any automobile may be and is used, are of two general classes; namely, *motor busses* and *taxicabs*. The latter are usually designed to

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carry four passengers and considerable baggage as well. They are used extensively in cities, where they are very popular for making short business and pleasure trips. Motor busses are usually operated on certain main city thoroughfares where there are no street-car lines, and are also used quite extensively in transporting passengers from town to town, where the railroad facilities are not good, or where there are no railroad accommodations at all. They carry a large number of passengers, some inside and some on top of the vehicle, and make regular trips at stated intervals between specified points, stopping to take on or to let off passengers at street crossings whenever signaled to do so. What are known as "sightseeing" motor vehicles are automobiles especially designed for the transportation of a large number of passengers on sightseeing trips, the places of interest along the selected routes being pointed out and described by the man in charge of the vehicle.

Jitneys are chiefly automobiles of the popular-priced variety of the touring-car class, running as a general rule over a specified route at a fairly regular time schedule, and may or may not run on thoroughfares on which there are no street car lines. In many cases jitneys run in direct competition with street-car lines, but there is a strong tendency in legislative bodies to limit their use to streets, roads, and highways not adequately served by existing electric and steam railroads, requiring the jitney owner to obtain a certificate of public convenience from the Public Service Commission, where such a commission or a similar public body is in existence, and file an indemnifying bond in addition, at least in many cases.

At present, most automobiles are driven by internal-combustion engines using gasoline as fuel, the power developed by the engine being applied to the driving road wheels by means of suitably arranged power-transmitting mechanism.

GENERAL ASSEMBLY OF THE AUTOMOBILE

2. There are two principal parts to an automobile; namely, the *chassis* (pronounced *shah-see*) and the *body*. As originally employed by the French, from whom it has been borrowed,

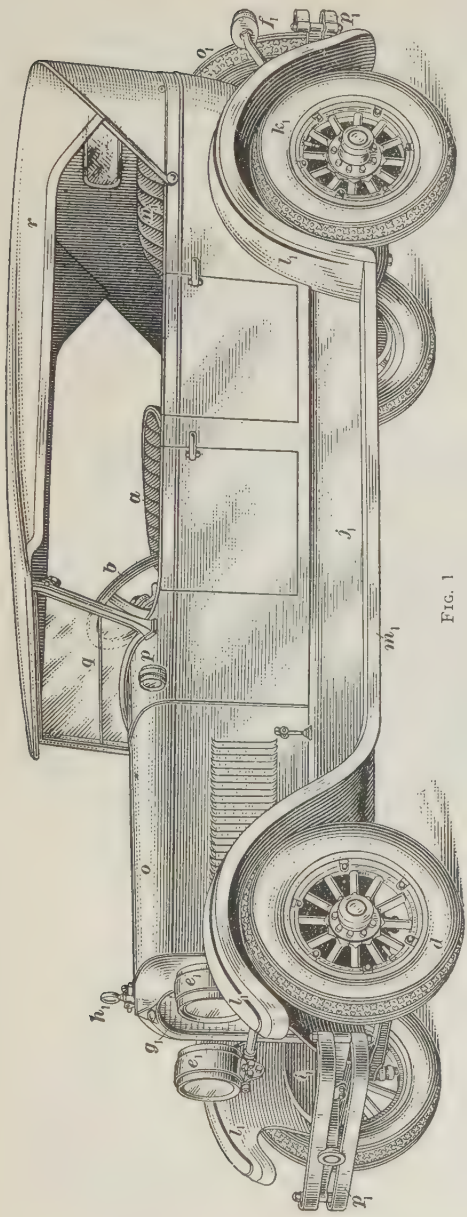


FIG. 1

the term chassis was used to designate only the frame of the automobile, but as now used it applies to the assembly of the running gear, consisting of wheels, axles, springs, and frame, and the power plant, which includes the engine and transmission. In other words, the chassis includes everything but the body and accessories. Before considering in detail the construction of the various parts of the chassis, attention will be given to the assembled parts of the automobile as a whole, the names, location, arrangement, purpose, and relations of the principal parts being noted. In conjunction with this, it should be noted that while automobiles produced by different manufacturers greatly resemble one another in their general features, there is naturally a great difference in the design of the details and

the location and arrangement of many parts. For this reason, some of the details of the description of an automobile given here apply to only the particular motor car that is illustrated, the general features of this automobile, however, being common to all of the same type.

The various component parts of an automobile are here treated in a general way, and their construction, functions, operation, and management are explained in detail in the proper places.

3. Three illustrations of a Marmon five-passenger automobile of the touring class are presented in Figs. 1, 2, and 3. In Fig. 1 is a perspective view of the left side of the car; in

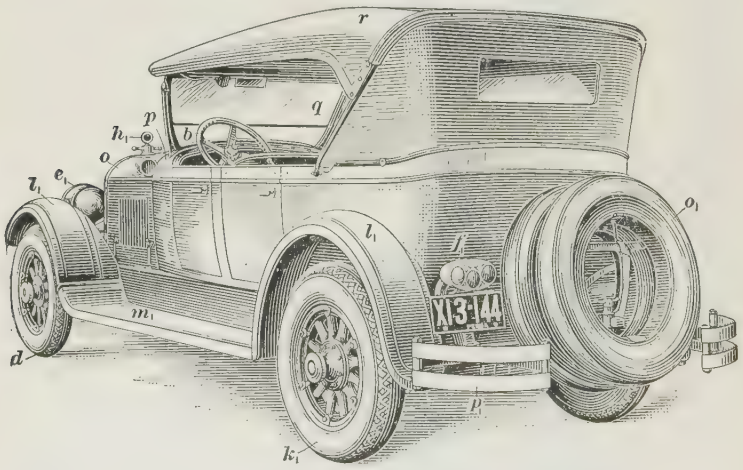


FIG. 2

Fig. 2 is a view of the same side of the car, taken from the rear; and in Fig. 3 is a view of the front compartment of the body, as seen from the right side of the car. In connection with this, it should be noted that the right side of a motor car is the one at the right of the observer when he is in one of the seats and is facing toward the front; under the same conditions, the left side of the motor car is at his left.

The automobile shown is intended to seat two persons in front and three in the rear; the driver of this car sits at the

left, as is now the usual practice, but in some of the older makes of automobiles, and in most of those built for export, the driver sits at the right.

As far as possible, the same parts are lettered alike in Figs. 1, 2, and 3, and all three illustrations should be referred to in reading the description.

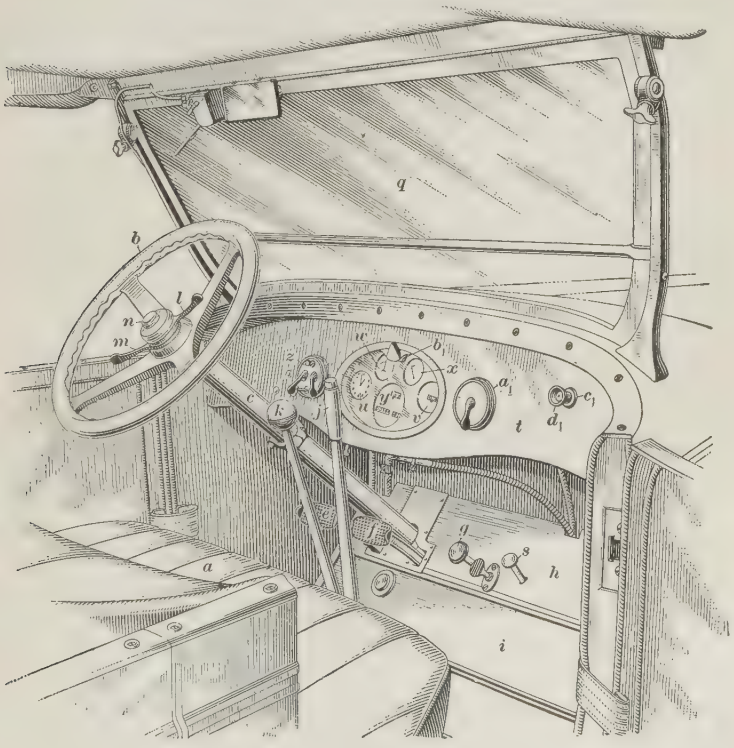


FIG. 3

Just in front of the driver's seat *a*, is a steering wheel *b* at the top of the inclined steering column *c*, which can be clearly seen in Fig. 3. The guiding of the car is accomplished by rotating this wheel through part of a revolution by hand. This rotation transmits motion to the front road wheels *d*, Figs. 1 and 2, so as to turn them sidewise and change the direction of travel of the car.

Pedals *e*, *f*, and *g*, which can be seen only in Fig. 3, project through the floor of the front compartment, the board *h* being known as the toe board, because it is under the toes of the driver. The part *i* of the front-compartment floor is known as the foot-board. The clutch pedal *e* is used for engaging the engine with the driving mechanism or disengaging the engine from it. The service-brake pedal *f* is used for applying the brakes ordinarily employed in regular service to slow down the car or to stop its travel. The accelerator pedal *g* is used for increasing or decreasing the speed of the engine. All three pedals are operated by the pressure of the driver's foot.

4. Near the center of the front compartment, and just forward of the driver's seat, are located two levers *j* and *k*. One, the hand-brake lever *j*, controls a set of brakes independent of the service brakes, and is used for applying these brakes in an emergency, either in conjunction with the service brakes or alone in case the service brakes are out of order or it is considered undesirable to use them. The other lever *k*, which is called the gear-shift lever, is employed for adjusting the power-transmitting mechanism, so that the speed of travel of the car can be varied through a greater range than that obtainable in the engine, and also for giving the car backward travel. This arrangement is useful and generally necessary in order to obtain both high and low speeds of travel, and also in order to be able to climb steep hills. A gasoline engine such as is used on automobiles rotates in only one direction and cannot be run at very low speeds. The minimum speed of rotation of automobile engines is probably never as low as 100 revolutions per minute and generally not lower than 200, 300, or even more, according to the size and form of the engine.

On top of the steering wheel *b* are two small levers *l* and *m*, Fig. 3, for controlling the power and speed of the engine. Each of these levers is attached to a shaft, or tube, that extends down inside the steering column that supports the steering wheel. One of the levers is for regulating the amount of fuel delivered to the engine, and the other is for regulating the instant at which the fuel is ignited. The lever *l* for regulating

the supply of fuel is called the throttle lever; the lever *m* for regulating, or varying, the time of ignition is called the spark lever.

A button *n*, called the horn button, on top of the steering wheel, when depressed closes a switch, thus sending an electric current to the signal horn, which is carried out of sight under the hood *o*, Figs. 1 and 2, covering the engine. The part *p* of the body, on which rests the rear of the hood *o*, is called the cowl; on it is supported the wind shield *q*, the purpose of which is to protect the occupants of the front seats from rain or dust, to prevent the impinging of air against the upper part of their bodies on account of the forward motion of the car, etc. The wind shield is made in two sections, the lower section being stationary, and the upper section so hinged to the wind-shield supports that it can be adjusted to any angle desired. The wind-shield supports also serve as points of attachment for the forward part of the top *r*, suitable clamps being placed inside the top for this purpose.

In the car here illustrated, as in all modern American cars, the engine is arranged to be cranked by means of an electric motor in order to start it; the current is sent from a storage battery to the electric motor by depressing the button *s*, Fig. 3, with the foot, thereby closing the starting switch.

5. In front of the driver and at the upper part of the cowl there is located the cowl board *t*, also called the instrument board, on which in this particular case are carried the clock *u*; the gasoline gauge *v*, which shows the amount of fuel in the tank; the ammeter *w*, which shows whether the storage battery is being charged or discharged and at what rate; the oil-pressure gauge *x* of the engine-lubrication system; the speedometer *y*, which shows in miles per hour the speed of the car and also in miles the distance traveled; all mounted in the same panel, and under one glass. The combined lighting and ignition switch *z*, and the carbureter air-choke lever a_1, used for cutting off the air supply to the carbureter to promote easy starting of the engine, are also located on this board. The cowl board is electrically lighted by the lamp b_1. A lamp

socket c_1 is provided on the dash for a cigar lighter d_1, as shown, or to permit attachment of a portable lamp to the lighting system of the car for inspection of parts at night; such a portable electric lamp is called an inspection lamp.

The fuel for the engine of this car, as is the case with all other gasoline cars, consists of a mixture of the right proportions of gasoline vapor and air. This mixture is formed in a device called the carbureter, the liquid gasoline in this particular case flowing to the carbureter by gravity from a small tank carried under the hood and fed by a large tank located at the rear end of the car.

The Marmon car, in common with other modern cars, is equipped with electric head-lamps e_1, Figs. 1 and 2, which illuminate the road by throwing a clear white light ahead; the headlights are equipped with non-glare lenses to prevent blinding persons facing the car. A lamp, called a tail-lamp, is always arranged to show a red light toward the rear, thus indicating to an observer that he is looking at the rear of the car. The tail-lamp is also arranged to throw a white light at right angles to the car for the purpose of illuminating the rear license tag. The tail-lamp shown at f_1 in Figs. 1 and 2 is combined with a stop light, and a backing light. While the engine is running, the electric current for lighting the lamps is normally furnished by means of a generator, which is driven by the engine; when the engine is stopped, the electric current is furnished by a storage battery.

A radiator g_1, Fig. 1, is mounted at the extreme front of the car; its purpose is to cool the water used for keeping the engine cylinders from becoming too hot. Mounted on the radiator (in this particular case) is a thermometer h_1, known to the trade as the motometer, which indicates the temperature of the water in the radiator.

6. The engine, which cannot be seen in any of the illustrations, is located in the front of the car under the hood o between the radiator and the cowl; at the bottom and in front of the engine is placed the engine shield i_1, Fig. 1, which protects it from mud and loose road dirt to a large extent.

The body of the car, consisting of the front and rear seats, together with the necessary doors to give access to the seats, is mounted on the frame j_1. The car is driven by the rear wheels k_1, which are rotated by the engine. Fenders l_1 are placed over all the wheels to prevent mud from splashing over the occupants of the car; these fenders are connected to running boards m_1, which serve as steps to facilitate entering and leaving the front and rear compartments of the body. Springs are interposed between the frame of the car and the axles on which the road wheels are mounted, in order that the occupants may ride over the road in comfort.

The rear seat n_1, carries three passengers. Some cars have auxiliary seats in the rear compartment, which can be folded down out of the way when not in use.

One or more spare tires o_1, fully inflated on spare rims, are carried by a suitable carrier at the rear of the car. One or more bumpers p_1 are generally placed on the car to protect it in case of collision.

METHODS OF PROPELLING THE CAR

APPLICATION OF POWER

7. Automobiles have in the past been propelled by rotating all four wheels, by rotating the rear wheels only, or by the front wheels only. The method of driving all four wheels simultaneously is used to some extent on motor trucks, but it is not employed on any of the so-called passenger cars. Propelling a car through its front wheels has been tried out with some degree of success, but no stock cars embodying this feature are built at the present time. All gasoline automobiles are now propelled by rotating their rear wheels, by use of a rotating shaft and bevel gearing, the car thus being shaft-driven.

Other means of driving the rear wheels of cars have been used, such as driving by chains and sprockets, or by a friction gearing, but the number of cars still in service employing such unconventional methods of driving is so small that detailed descriptions of these methods are not warranted here.

NOMENCLATURE OF TYPICAL CHASSIS PARTS

8. A top view of the Buick Six chassis, with the body, fenders, and running boards removed, is shown in Fig. 4. The various component parts are numbered; as far as possible they are named in accordance with the nomenclature adopted by the Society of Automotive Engineers (formerly the Society of Automobile Engineers), the name being abbreviated to S. A. E.

1, Left front wheel.

2, Right front wheel.

3, Front axle center.

4, Left steering knuckle.

5, Right steering knuckle.

6, Steering-knuckle tie-rod, or distance rod.

7, Steering-gear connecting-rod, one end of which is attached to an arm of the left steering knuckle, the other end of the steering rod being connected to the actuating lever arm of the steering gear.

8, Radiator in which water for circulation in engine water-jackets is cooled.

9, Fan, to create circulation of air through radiator, thus cooling water therein when the car is standing still while the engine is in operation, and aiding circulation while the car is running.

10, Cross-member of frame; in case there are two cross-members, they are called the front and rear cross-members; in case of three, the center one is known as the center cross-member; in case of more than three, they are called the first, second, etc. cross-members, beginning the count at the front.

11, Left frame side member.

12, Right frame side member.

13, Water pump.

14, Lower radiator hose, joining the bottom of the radiator to the water-pump inlet.

15, Upper radiator hose, joining the top of the water pump to the cylinder jacket.

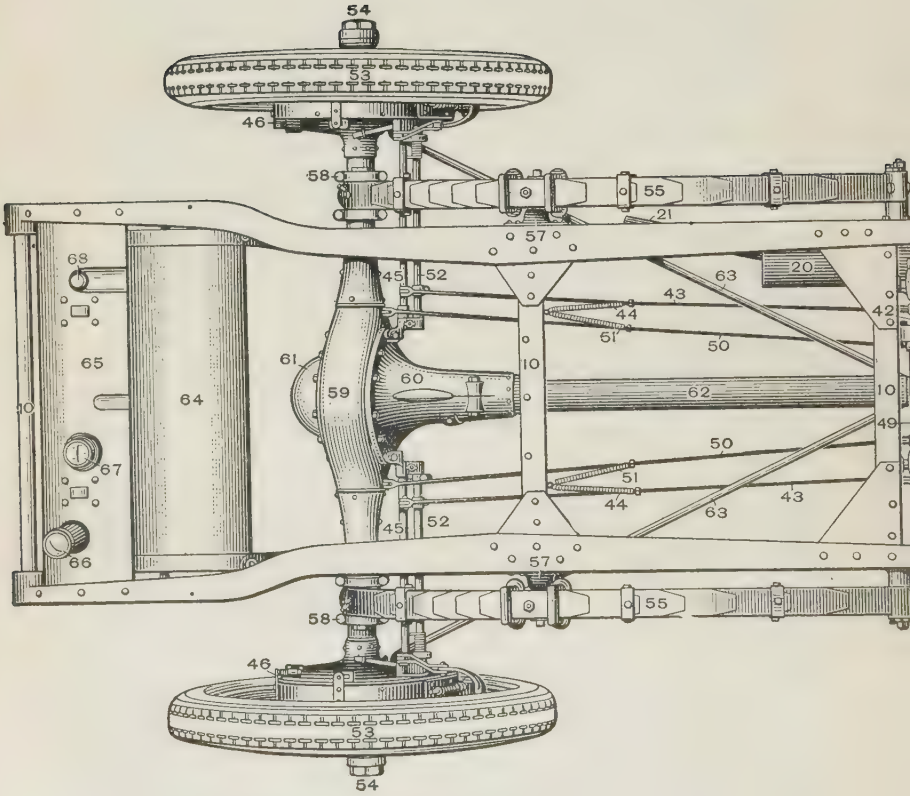
16, Cover over the cylinders, which in this case are cast in block, or in one piece. Under this cover are the valves and their operating mechanism.

17, Ignition high-tension cables conveying the high-tension current from the ignition apparatus to the spark plugs, which are in the side of the cylinder head and not visible in the illustration.

18, Exhaust manifold.

19, Exhaust pipe joining the exhaust manifold to the muffler.

20, Muffler.



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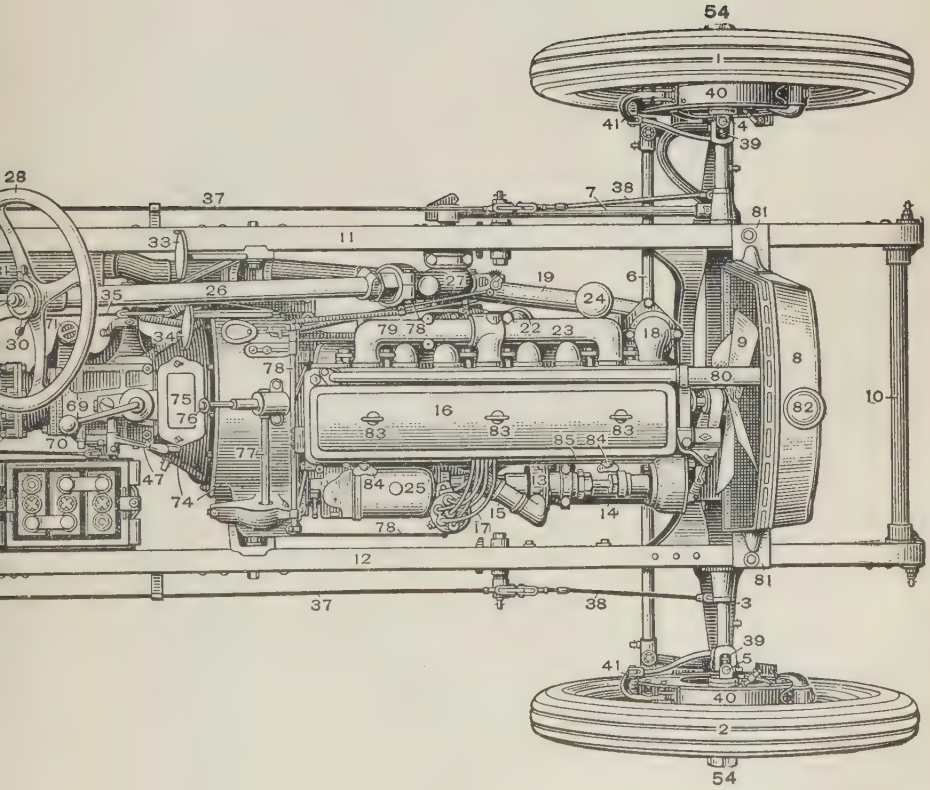
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21, Muffler outlet pipe.
22, Carbureter.
23, Intake manifold.
24, Breather, or oil filler, which connects with the inside of the crank-case.
25, Motor-generator for cranking the engine by current from a storage battery carried in a convenient location in the car, and for supplying current for the lights and ignition when the engine is running.
26, Steering-column tube.
27, Steering-gear case.
28, Steering-wheel rim.
29, Steering-wheel spider.
30, Spark lever.
31, Throttle lever.
32, Horn button.
33, Clutch pedal.
34, Service-brake pedal.
35, Service-brake operating rod.
36, Front-wheel brake operating shaft.
37, Front-wheel brake operating rod, right and left.
38, Front-wheel brake adjusting cable, right and left.
39, Front-wheel brake universal joint, right and left.
40, Front-wheel brake band, right and left.
41, Front-wheel brake bell-crank, right and left.
42, Rear service-brake operating shaft.
43, Rear service-brake operating rod, right and left.
44, Rear service-brake release spring, right and left.
45, Rear service-brake rod, right and left.
46, Rear service-brake band.
47, Emergency-brake lever.
48, Emergency-brake pull rod.
49, Emergency-brake operating shaft.
50, Emergency-brake operating rod, right and left.
51, Emergency-brake release spring, right and left.
52, Emergency-brake rod, right and left.
53, Rear wheel, right and left.
54, Wheel hub caps, right and left.
55, Rear spring, right and left.
56, Rear-spring front bracket, right and left.
57, Rear-spring rear bracket, right and left.
58, Rear-spring seat, right and left.
59, Rear-axle housing.
60, Differential carrier (bolted to rear-axle housing).
61, Rear-axle cover-plate.

62, Propeller-shaft housing.
63, Strut rod, right and left.
64, Gasoline tank.
65, Gasoline-tank shield.
66, Gasoline-tank filler opening cap.
67, Gasoline-tank gauge.
68, Gasoline-tank connection to carbureter.
69, Transmission case.
70, Gear-shift lever.
71, Transmission-case filler opening cap.
72, Universal joint.
73, Storage battery.
74, Flywheel and clutch housing.
75, Clutch-housing cover-plate.
76, Starter pedal.
77, Starter shaft (shaft connecting starter pedal to starting mechanism).
78, Spark-control linkage.
79, Throttle-control linkage.
80, Upper radiator hose, joining the top of the radiator to the water manifold leading to the top of the cylinder jacket.
81, Radiator support, right and left.
82, Radiator-filler opening cap.
83, Thumb, or wing, nuts holding the cylinder-head cover in place.
84, Thumb, or wing, nuts holding the spark-plug cover in place.
85, Spark-plug cover.

DRIVING-MECHANISM ARRANGEMENTS

9. Different arrangements of the engine, the clutch, the transmission, and the rear axle have been in use in automobiles in the past, but the following general arrangement is now used in practically every car employed for private purposes. The engine, with which the clutch is almost always combined, is placed at the front end of the car with its crank-shaft in the direction of the length of the car, the transmission being placed directly behind the engine. The only exception to this is in the Ford car, in which the clutch is enclosed in the same casing as the transmission. In the great majority of cars, use is made of an engine with either four or six vertical cylinders, while in other cases, eight cylinders are employed, the cylinders being arranged either in two groups of four cylinders, the two groups having an angle of 60° or 90° between them, or in single line.

Engines having the cylinders at an angle to each other are known as the **V**-type (*vēē type*) engines. Many types of twelve-cylinder **V**-type engines have been brought out during the past few years, but none of these is used as regular equipment at present in American-built cars. In many cases the engine, the clutch, and the transmission are combined in a single rigid unit; the combination is then known as a unit power plant.

The engine of an automobile is bolted to the frame and the rear axle is connected to the frame by one or more springs. Consequently, the distance of the rear axle from the frame and the engine is constantly changing with different loads and under different road conditions. Furthermore, the center line of the crank-shaft and the center line of the driving, or propeller, shaft are not normally in the same straight line, although they always intersect. From this it can be seen that a yielding connection must be made between the power plant and the driving shaft so as to compensate for any variation in the distance between the axle and the engine, and any disalinement between the propeller shaft and the engine, either in the original design or that caused by the compression and extension of the rear springs. This yielding connection is in practice made possible by one or more universal joints.

The application of the power of the engine to the driving wheels or the application of the brakes on the rear wheels of the car, tends to rotate the whole rear-axle housing around its center line in a direction opposite to that in which the wheel turns. Various methods are employed to overcome the turning or twisting effort, known as torque, in the axle housing. In some cases the propeller shaft is enclosed in a housing that is fastened rigidly to the rear-axle housing; in others, separate arms or tubes, known as torque or torsion arms, are employed; while in still others, the springs themselves are depended upon to prevent the axle housing from turning.

Means must be provided also to keep the rear axle in alinement with the remainder of the car. Methods used to overcome the torsion in the rear-axle housing also serve for this purpose in many cases, but in some cars, separate radius rods are employed.

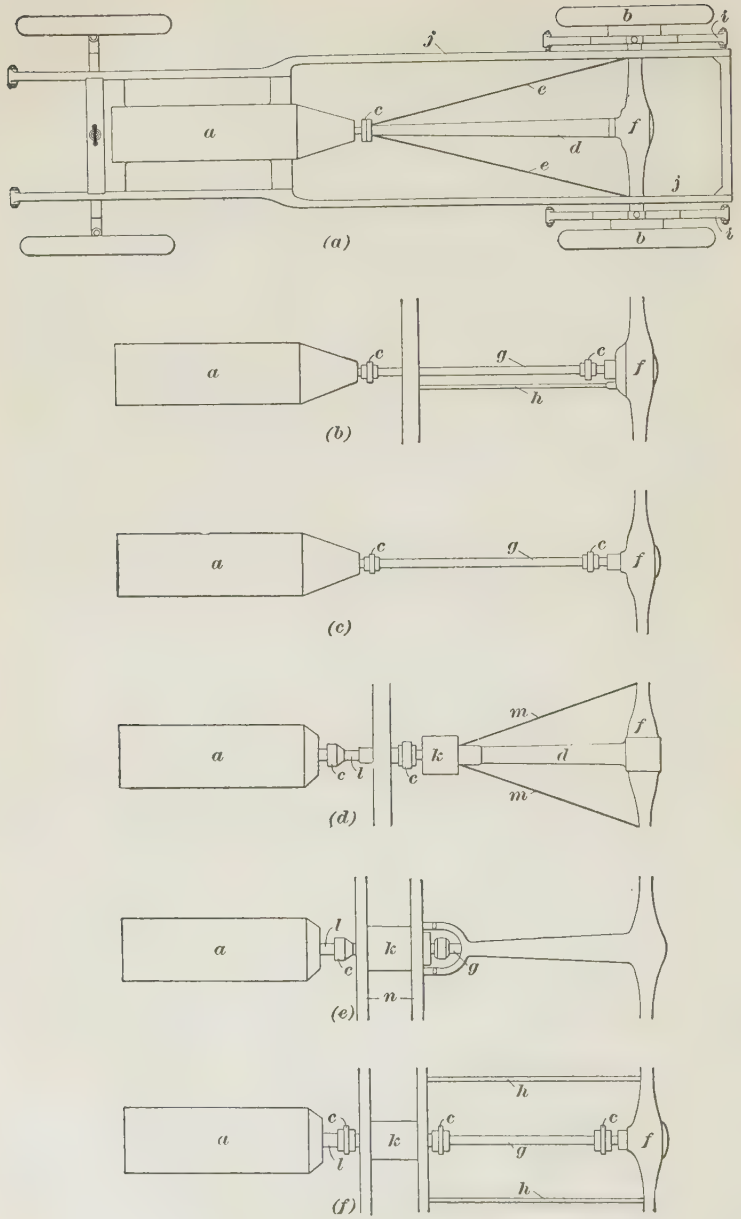

FIG. 5

10. The most common of the driving-mechanism arrangements are shown diagrammatically in the various views of Fig. 5, and are as follows:

1. A unit power plant *a*, view (*a*), drives the rear wheels *b* through a propeller shaft having at its forward end a single universal joint *c*, the shaft being enclosed in a torque tube *d*. Radius rods *e* are employed to hold the axle *f* in alinement.

2. A unit power plant *a*, view (*b*), drives the rear wheels through an unhoused propeller shaft *g* with a universal joint *c* at each end, a torque arm *h* preventing the rotation of the rear-axle housing *f*. The front ends of both rear springs are hinged to the frame, and as the springs are also bolted at their middle to the rear-axle housing, they serve to hold the axle at right angles to the frame. The car is driven through the springs.

3. A unit power plant *a*, view (*c*), drives the rear wheels through an unhoused propeller shaft *g* with a universal joint *c* at each end. The front ends of the rear springs are hinged to the frame, the rear axle thus being confined in relation to the frame, and hence no radius rods are required. Furthermore, as each rear spring is rigidly attached to the axle housing, the rotation of the housing is prevented by the springs, and hence no torsion member is required. The method of preventing the rotation of the rear-axle housing by the rear springs and also driving the car through them is known as the *Hotchkiss drive*.

4. The engine and clutch form a unit *a*, view (*d*), that drives the separate transmission *k* through a short shaft *l* with two universal joints *c*, the transmission being carried by the forward end of the torque tube *d* enclosing the propeller shaft. The tie-rods *m* are used to keep the forward end of the propeller-shaft housing properly lined up in relation to the rear-axle housing *f*.

5. The engine and the clutch form a unit *a*, view (*e*), that drives the separate transmission *k* through a short shaft *l* and a flexible coupling *c*. The transmission is fastened to the cross-members *n* of the frame of the car, and transmits the power of the engine through a single universal joint, and an enclosed propeller shaft *g* to the rear axle.

6. The engine and the clutch form a unit *a*, view (*f*), that drives the separate transmission *k* through a short shaft *l* and a flexible coupling *c*. The transmission transmits the power of the engine through an unhoused propeller shaft *g* having a universal joint *c* at each end. Separate torque arms *h* are employed to prevent the rotation of the axle housing *f*.

TYPES OF BODIES

GENERAL CLASSIFICATION

11. The body of an automobile is the part that provides accommodations for the passengers. It is the superstructure that rests on the frame of the chassis and that carries the dash, the wind shield, and the top.

Bodies may be classified under two main heads; namely, open bodies and closed bodies. There is such a variation in the different models brought out by some of the manufacturers, however, that it is sometimes difficult to designate the particular class to which each type really belongs. Some of the cars listed under open cars have permanent tops, and, therefore, really belong in the closed-car class. Others might well be classified as convertible bodies, as they are open during certain months, and closed during the others. A closed car is usually understood to mean one with permanent uprights to which the top and wind shield are fastened, and which has solid door and window frames, and plate-glass windows.

BODY NOMENCLATURE

12. The Society of Automotive Engineers (S. A. E.) has adopted a standard nomenclature for automobile bodies. This nomenclature, however, is not followed very closely by automobile manufacturers, there very often being different models carrying the same name, while in other cases, similar models are called by vastly different names by individual manufacturers.

The S. A. E. standard nomenclature follows:

The *roadster* is defined as an open car seating normally two or three people and it may have additional seats on the running boards or in the rear deck. For protection of the occupants it is fitted with a folding top, which, when folded down, is covered with a slip top cover.

The term *runabout* is applied to this model by some manufacturers.

The *coupélet* is a roadster with a closed body; it is defined as a car seating two or three persons, with a folding top and full-height doors with disappearing panels of glass. When the top is folded down the car is virtually an open roadster.

The *coupé* is a car with a permanent closed body, and is defined as an inside-operated enclosed car seating two or three persons, with a seat facing backwards for a fourth person, sometimes added. The chief point of difference between the coupélet and the coupé is that the former has a folding top while the latter has a permanent top.

There seems to be a tendency on the part of body makers to wander away from the original definition of the term coupé, as the term now is applied to a variety of body styles, some being of the two-door five-passenger variety with two full seats, others of the four-door five-passenger variety, and so on. Some makers have applied the terms *victoria* and *coupé-roadster* to bodies coming under the coupé classification, as originally intended.

13. The *touring car* is defined as an open car seating four or more persons, having doors giving direct entrance to the *tonneau* (the rear compartment of the body), and an undivided front seat. Touring cars are generally equipped with a folding top and a wind shield.

The tendency is more and more at the present time to get away from the folding top in open cars, a permanent, rigid, top being used instead. There is also a tendency to discard the name touring car, on the grounds that the name is not entirely appropriate, other cars also being used extensively for touring purposes. The name phaeton is preferred by many manufacturers.

A *convertible touring car* is defined by the S. A. E. as a touring car having a folding or a permanent top and disappearing or removable glass sides.

The term has also been applied largely to touring cars having a detachable top with glass sides, which was removable as a unit, and when removed, after replacing the regular folding top, left the car a regular touring car.

A *sedan* is defined as a closed car with a permanent top, seating four or more persons all in one compartment.

The sedan is made in a variety of forms, some makes having two doors and others four. Some of the two-door variety

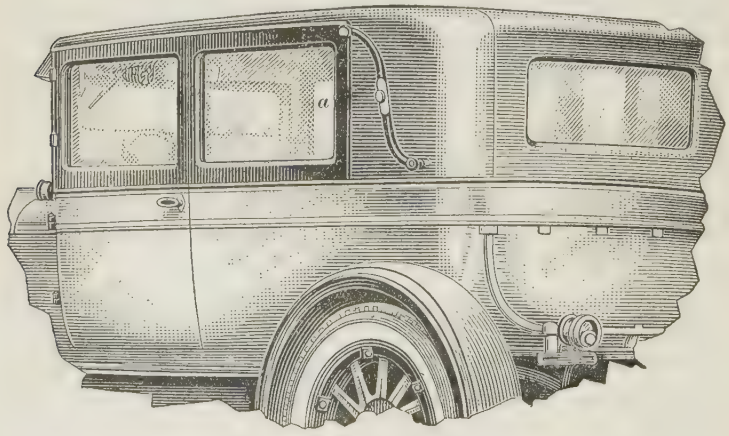

FIG. 6

have individual front seats that may be folded forwards to allow the entrance of passengers through the front compartment to the rear seat. Others have front doors of such width that, when open, they permit ingress to either the front or the rear compartment directly. The term *coach* is applied by some manufacturers to a form of sedan having two fore doors, and in which there is only a short space between the rear seat and the back of the front seat. In one or two cases the term *brougham* is applied to a form of sedan having an external imitation-hinged brace, as shown at *a*, Fig. 6, the brace giving the appearance of a collapsible rear section. The rear section, however, is stationary.

14. The *limousine* is defined as a closed car seating three or five in the rear compartment, with the driver's seat outside, covered only with a roof. The top and glass sides are permanent parts of the body, and there is a glass partition between the front and rear compartments.

In some cars of this type, the full width window between the driver's compartment and the passenger section may be lowered, making the car a combined limousine and sedan.

The *berline* is a limousine having the driver's seat entirely enclosed. The front seats are not divided, and separate doors give entrance to the front and rear compartments. The top is a permanent part of the body.

The *landaulet* is defined as a closed car with a folding top, seats for three or more passengers inside, and the driver's seat outside. There is a roof over the driver's seat, and only the part of the top over the rear seats can be folded down.

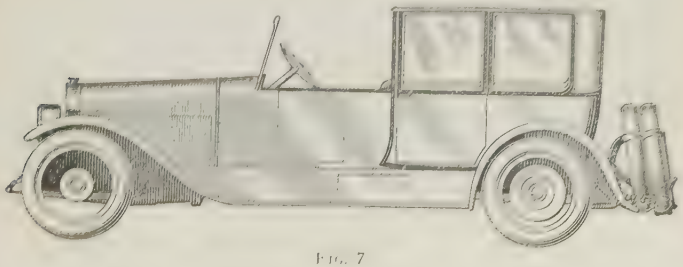

FIG. 7

The *brougham,* shown in Fig. 7, is defined as a limousine with no roof over the driver's seat. Consequently the wind shield is the only permanent protection of the driver. The top is a permanent part of the body. A covering of water-proof fabric and side curtains are provided for attachment on this type of car to protect the driver in inclement weather. This type of car is often referred to as a *town car* also.

When a car of this type has a collapsible rear section, as shown in Fig. 8, it is known as a *cabriolet.* If the rear end of the car is simply provided with a small folding top, similar to that employed on a roadster, the car is generally known as a *victoria.*

The term *sport* is used with different models of cars when they are supplied with equipment or have details of design not employed in the regular models. Thus a sport touring car is equipped with nickel-plated parts wherever practicable; with

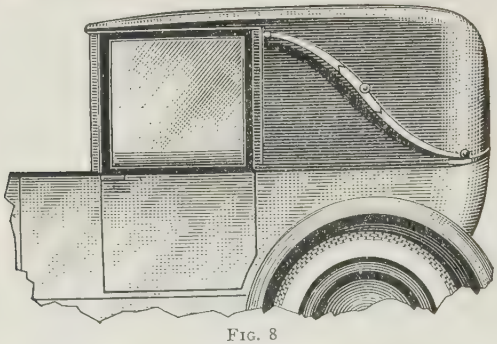

FIG. 8

wire or disk wheels, usually; extra equipment, including one or more spare tires, and so on. Often the purchaser is allowed to have a choice of colors when buying a sport car.

OPEN-BODY ENCLOSURES

15. It was formerly the practice to equip all cars of the open type with folding tops. The majority of such cars are still equipped with the folding top, but the tendency to drive with the top down has been growing less each year, owing largely to the fact that the folding of the top soon gives it an unsightly appearance. Many manufacturers, taking advantage of this fact, are equipping their cars with permanent tops, and thus gain many of the advantages of the closed car without losing any of those of the open type. Some manufacturers go a little further than this, and provide two tops, a solid top for winter driving and a folding top for the summer months.

Open-car tops are regularly equipped with side curtains for enclosing the occupants in bad weather. These curtains are made to fit and have large windows that conform to the lines of the car. The side curtains are usually detachable, so that they can be removed entirely and carried in some convenient place when not needed, or they are arranged permanently in

place so that they may be rolled up or down in the manner of the roller type of window shade found in houses. Detachable

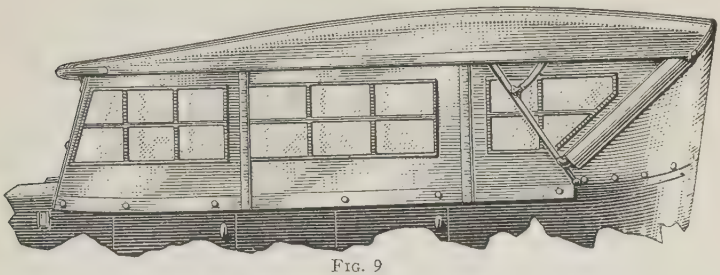

FIG. 9

storm curtains in place on the car are shown in Fig. 9, while the rolling type is shown in Fig. 10. The car shown in Fig. 10 is equipped with a permanent top, having a steel frame.

In Fig. 11 is shown an enclosed top on a touring car. Spe-

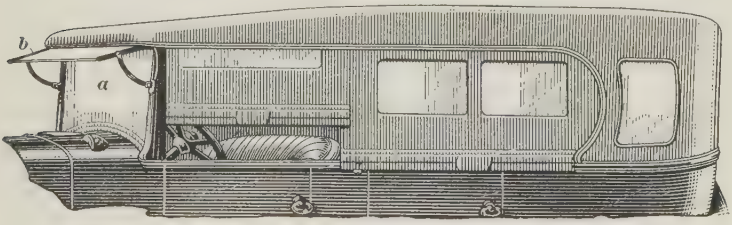

FIG. 10

cially built glass sides fit snugly against the permanent top, and afford protection to the occupants against the weather. The glass windows slide open for ventilation, and a heater is usually built into the car to assure comfort in cold weather. Instead

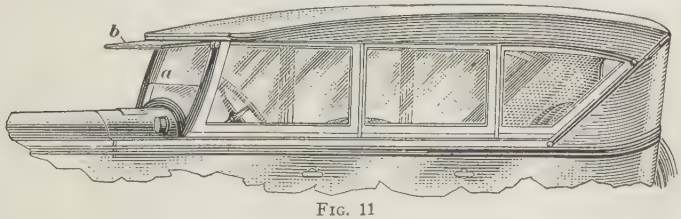

FIG. 11

of having a special top for the winter season, some makers have glass enclosures to fit the regular top, whether it be permanent or folding.

WIND SHIELDS

16. A *wind shield* is a device attached to the cowl of an automobile body, and sometimes to the back of the front seats as well, for the purpose of protecting the occupants of the car from dust, rain, cold winds, etc. Wind shields consist of glass supported by metal frames, and they are usually so constructed that they may be tilted at different angles.

The wind shields most commonly used are of the rain-vision type; that is, they are made in two parts, so that the lower edge of the upper section may be tilted forwards during rainy weather. A good view of the road is thus obtained between the sections of the wind shield. Some cars, especially closed cars, are equipped with fixed or stationary one-piece shields. It is claimed that the one-piece fixed wind shield will exclude rain better than any adjustable one. It is necessary to provide ventilators above the shield, when the fixed type is employed. The rain-vision wind shield is shown at *a* in Fig. 11, and the one-piece type at *a* in Fig. 10. A visor, shown at *b*, Figs. 10 and 11, forms a part of the regular equipment of most modern cars. The visor protects the occupants of the front seat from the glare of the sun, and also gives some protection against rain or snow.

AUTOMOBILE RUNNING GEAR

WHEELS AND AXLES

WHEELS

17. Types of Motor-Vehicle Wheels.—Most automobiles are equipped with wooden wheels of the so-called artillery type, a form of wheel used on gun carriages and one capable of withstanding severe shocks under heavy loads. Wire wheels, that is, wheels with wire spokes, are also used quite extensively, especially on sport-model cars, although the disk wheel is much used for such cars. The disk wheel is also used quite extensively on regular models. Wooden wheels are known as *compression wheels*, because the spokes in the bottom half of the wheel carry the weight and are therefore in compression. Wire wheels are known as *suspension wheels*, because the spokes supporting the hub are in tension, that is, drawn up tightly, and the load may be said to be suspended by these spokes. Disk wheels, because of the integral steel disks, carry the weight in both compression and suspension.

18. Wooden Wheels.—Wooden wheels are usually constructed with spokes set in a single circle around the hub, between the flanges of which they are securely clamped by means of bolts. As compared with wire wheels, this type of wheel is more easily cleaned, and is not subject to deterioration on account of rusting. Ordinarily, the spokes lie in a plane perpendicular to the longitudinal center line of the hub, but in a few cases they are dished; that is, they are set inwards at the hub and are not perpendicular to the center line of the hub. The dished construction is claimed by some manufacturers to give the wheel greater strength to resist lateral or

sidewise stresses, as when turning corners. In automobiles equipped with wooden wheels, it was formerly the custom, in some cases, to equip each front wheel with ten spokes and each rear wheel with twelve. It is the general practice now to provide both front and rear wheels with twelve spokes each.

19. The construction of a typical wooden wheel for automobiles is shown in Fig. 12. The wheel shown is intended for the rear of the car, but, with the exception of the mounting of the brake drum and the construction of the hub, it is identical with the wheel used at the front end of the car. As shown, the wheel is fitted with a demountable rim *a* that can be taken off quickly by removing or loosening the rim-bolt nuts *b* and the rim clamps *c*. The wooden rim *d*, known as the felloe, and the spokes *e* are bound in place by the steel band *f*, known as the felloe band, that is pressed over the felloe. The spokes *e* are fastened to the hub flanges *g* by the bolts *h*. The bolts *h*, as well as the bolts *i*, bind the brake drum *j* fast to the wheel. Part of the hole in the hub *k* is splined, that is, it has a number of slots similar to keyways, in order that the wheel may be driven by the splined end of the axle shaft. Other methods of mounting and driving the rear wheels are in use, and will be explained in the proper place. The hub caps *l* protect the hubs from dust or dirt, and give the wheel a finished appearance.

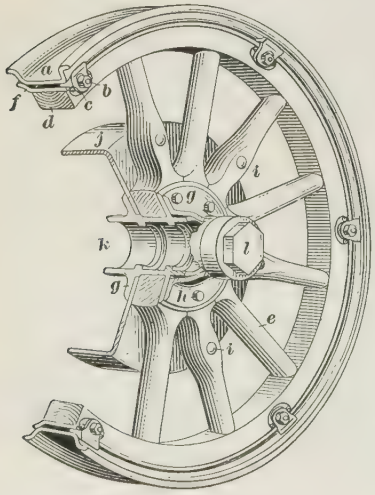

FIG. 12

20. In Fig. 13 are illustrated both the construction and the arrangement of the spokes in the Schwarz patent wheel, which is used on a large number of automobiles. The mitered

joints at the hub end of the spokes are made to overlap by using the mortise-and-tenon joint. When the spokes are assembled, the tenon *a* fits into the mortise *b*, the tenon *c* into the mortise *d*, and the inner tenons *a* and *e* are overlapped by the outer tenons *f* and *g*. The spokes are thus so interlocked that they cannot work loose, and they support one another in a compact, true assemblage. The spokes are put together under pressure with glue and their appearance when assembled is as shown at the right in the illustration.

21. Wire Wheels.—In some makes of wire wheels, the spokes are arranged about the hub in two circles, one set of spokes being attached to the inner hub flange and the other

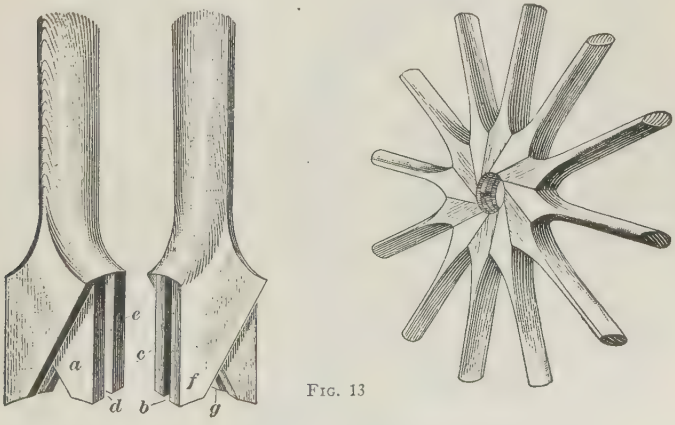

FIG. 13

set to the outer hub flange. In other makes three rows of spokes are employed, two rows being attached to the inner hub flange and the third row to the outer hub flange. All the spokes are tightened to exactly the same tension, so that they hold the hub in a central position and equalize the strain on the hub and the rim. The principal advantages claimed for wire wheels over wooden wheels are that they are stronger and will withstand a greater driving stress in proportion to their weight. It is also claimed that wire wheels keep cooler than wooden wheels, on account of their ability to radiate heat more readily,

and hence the tires are not affected to so great an extent by the heat generated when rotating rapidly.

Wire wheels for American cars are usually made demountable, that is, in such a manner that the whole wheel can be easily taken off the front axle or rear axle and replaced by a spare wheel, with a fully inflated tire mounted on it, that is carried on the car. The rims of wire wheels, the same as the rims of wooden wheels, are made to take the various types of tires, such as the regular clincher tire or one of the two kinds of quick-detachable tires; wire wheels are rarely made with demountable rims, however, it being the preferred practice to make the whole wheel demountable.

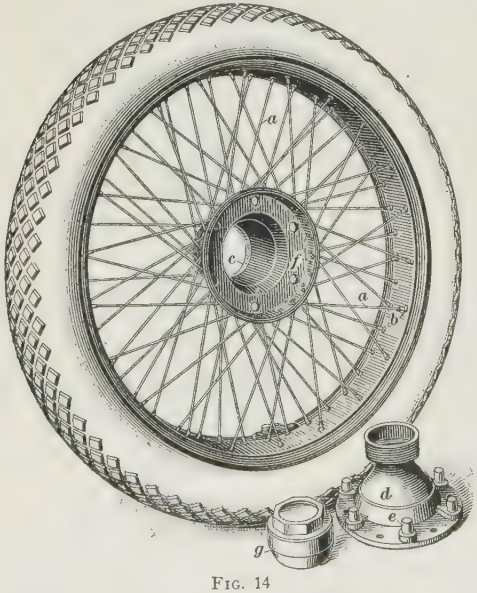

FIG. 14

22. The Houck demountable wire wheel shown in Fig. 14 is an example of an American made wire wheel; it has three rows of spokes. Each spoke *a*, just as is the common practice with bicycle wheels, is screwed into a nipple *b* passing through the rim. As in all demountable wire wheels, there are two hubs for each wheel, an outside hub *c* forming part of the wheel, and an inside hub *d* attached permanently to the front axle or rear axle. The inside hub has a number of pins *e* that enter corresponding holes *f* in the outside hub and force the two to rotate together; the two hubs are locked together by the hub cap *g*. These hub caps, or automatic locknuts, as they are called by the manufacturer of the wheels, tend to tighten themselves automatically; those on the left side of

the car have right-hand threads and those on the right side of the car have left-hand threads.

23. Disk Wheels.—The disk wheel consists of a central disk carrying at its outer edge and integral with it, a rim on which the tire is mounted. The wheel is demountable, and cars equipped with disk wheels are provided with a fifth wheel. This wheel, which is mounted on a carrier with a dummy hub, carries a fully inflated tire, and in case of tire trouble, the wheel with the damaged tire can be removed and quickly replaced by the spare one.

Disk wheels are usually made of pressed steel, although those made of laminated wood or aluminum are on the market. The advantages claimed for the disk wheels are that they are very easy to keep clean, are not subject to collapse under side thrusts, and will run absolutely true at all times, unless their contour is changed by the warping or bending of the disks through accident.

One type of the disk wheel is shown in section in Fig. 15. It consists of a central disk *a* to which the wide portion of the rim *b* is rigidly fastened. The tire *c* is held in place on the rim by the flange *d*, which, in the particular wheel shown, is fastened to the disk *a* by the rim bolts *e*. Other types of outer rim flanges are also common. To make a wheel change, all that is necessary is to jack up the wheel, remove the nuts *f*, take off the wheel, slip the spare wheel on to the hub bolts, and replace the nuts *f*. Only four nuts *f* are used in the disk wheel shown, but the use of five or more is not uncommon in other disk-wheel installations.

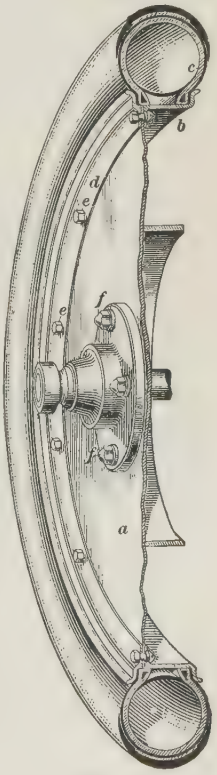

FIG. 15

24. Spring Wheel.—To obviate the use of pneumatic tires, and the troubles and expense connected with their maintenance, and at the same time to secure the easy riding qualities

of the pneumatic tire, many inventors have given a great deal of thought to the problem of producing commercially feasible elastic, or spring, wheels. Numberless designs have been produced, but spring wheels have never come into practical use.

FRONT AXLES

25. General Assembly.—The front axle of an automobile is made up of four parts; namely, a bar carrying the spring seats upon which the springs supporting the front part of the automobile rest, two steering knuckles carrying the spindles on which the wheels turn, and a cross-rod extending from one

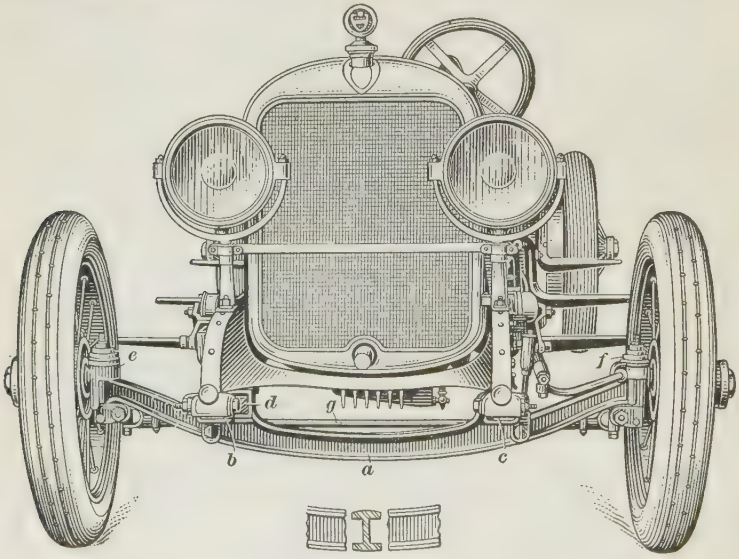

FIG. 16

steering knuckle to the other and tying the knuckles together so that they move in unison when the wheels are swiveled in steering. The location of these four parts is shown in Fig. 16. The main bar of the axle, called the front axle center, is shown at *a*, and at *b* and *c* are located the spring seats upon which the front springs *d* are carried. The steering knuckles *e* and *f* are pivoted at the ends of the axle center and are connected by the

steering knuckle tie-rod g which, in this automobile, is located back of the front axle, as is now the almost universal practice. At one time it was the common practice to have the tie-rod in

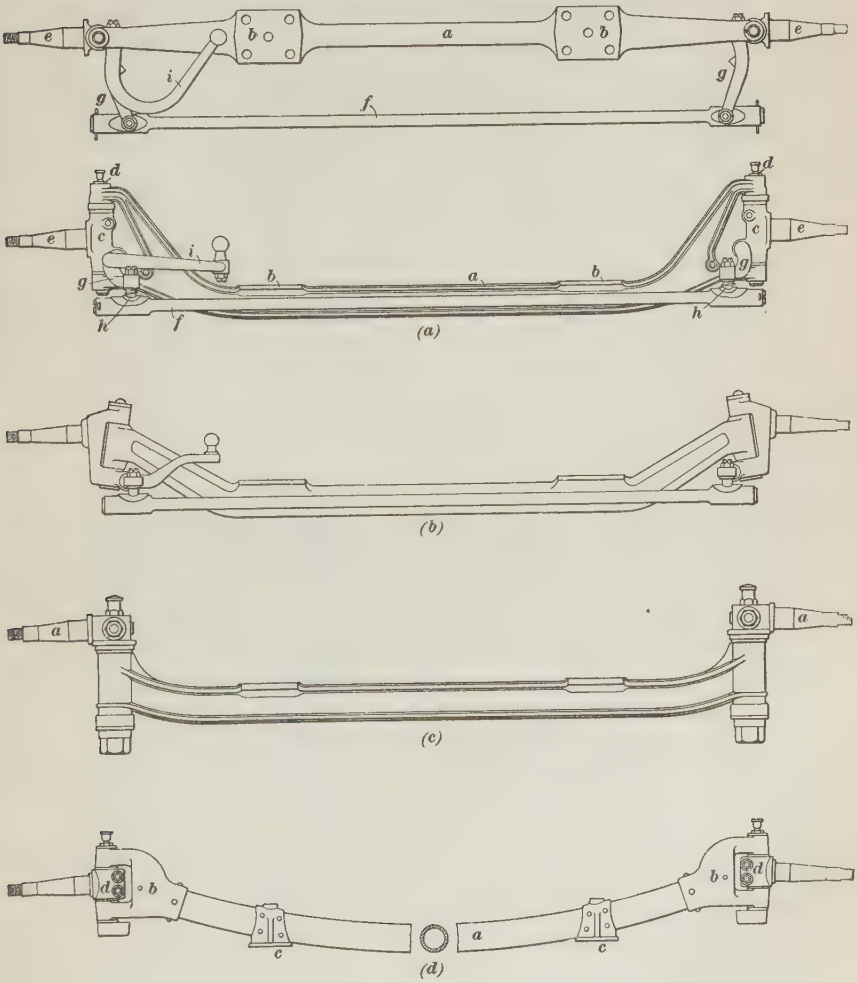

FIG. 17

front of the axle, as this gave a slightly better approximation to theoretically correct steering of the car than is obtainable by the present method; the danger of injury to the tie-rod when

placed in front has, however, led to the change in its location in nearly all cars.

26. The great majority of automobiles have forged-steel front axles of the I-beam type, as shown in Fig. 16, the name I beam being applied because of the shape of the axle section, it resembling closely the letter I, as shown in the small insert underneath the axle. In some cases, the axle center is made from steel tubing brazed to suitable fittings. Axle centers of the tubular type are used on Franklin and Chrysler cars.

27. Types of Axles.—Different types of solid front axles are illustrated in Fig. 17. The axle center *a* of the axle shown in (*a*) is made of a steel I beam. This center carries the spring seats *b* forged integrally with it, upon which the front springs rest; spring clips hold the springs in place. The steering knuckles *c* are pivoted in the yoked ends of the axle by the steering knuckle pivots *d*, and they carry the spindles *e* on which the front wheels rotate. The knuckles are connected by the tie-rod *f*, which is attached to the steering-knuckle arms *g* by means of ball-and-socket joints *h*. The tie-rod *f* and the steering knuckles are rocked to and fro during the steering of the automobile, by the steering-knuckle gear-rod arm *i* that is connected at its free end to the steering gear. Steering knuckles that fit in a yoke formed at each end of the axle bar are known as the Elliot type.

The steering knuckles of the front axle shown in (*b*), are known as the reversed Elliott type because the knuckles themselves are yoked, and their jaws fit over stub ends of the axle bar. The different parts of this axle perform the same functions as the corresponding parts of the axle shown in (*a*). The axle beam is of the I-beam type.

An axle of the I-beam type but employing a form of Lemoine steering knuckle is shown in (*c*). In this type of axle, of which only the front view is shown, the steering-knuckle spindles *a*, on which the front wheels revolve, are at the top of the axle center. Neither the steering knuckles nor the axle ends are yoked.

An axle of the tubular type is shown in (*d*). It consists of a center beam *a* of steel tubing, to which are brazed the yoke ends *b* and the spring seats *c*. The steering knuckles *d* are of the Elliott type.

28. Steering Knuckles.—In four-wheel horse-drawn vehicles, the spindles on which the wheels revolve form an integral part of the front axle, and steering is accomplished by turning the entire axle about its center. In automobiles, however, this construction is undesirable because of the difficulty that would be incurred in steering by hand at high speeds, as well as the lack of strength that would result. In order that the front axle bar of an automobile may be attached rigidly to the springs, and to obtain easy steering by turning the wheels through only

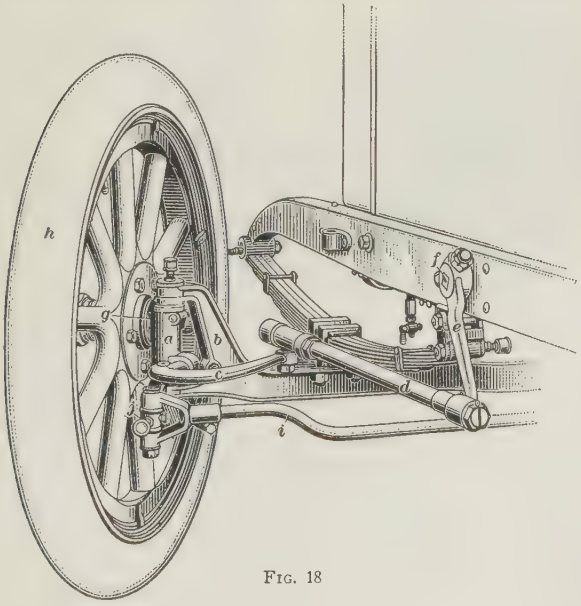

FIG. 18

a small radius, steering knuckles are provided. *Steering knuckles* are devices pivoted at the ends of the front axle of an automobile for the purpose of supporting the front wheels and allowing them to be turned without moving the axle center.

There are three types of steering knuckles used in present-day automobiles; namely, the Elliott, the reversed Elliott, and the Lemoine.

29. A common form of the Elliott steering knuckle is shown in place on the axle in Fig. 18, which is a view of the left-hand front wheel and steering connections as used on a modern left-hand drive automobile, looking from the rear of the car toward the front. The steering knuckle *a* is pivoted in the yoke *b* of the axle center, and it is operated from the hand steering wheel through the steering-knuckle gear-rod arm *c*, the steering-gear connecting-rod *d*, and the steering-gear arm *e* clamped to the steering-arm shaft *f*. The spindle *g* on which the road wheel *h* revolves is an integral part of the knuckle. This steering knuckle is connected to the knuckle on the right side of the car by means of the tie-rod *i*, which is attached to the steering knuckle arm *j*. When the steering wheel is turned, the rod *d* is moved forwards or backwards by the arm *e*, so that the knuckle, and, consequently, the road wheel, is turned to the left or the right by the arm *c*. The other front wheel is turned at the same time and in the same direction by means of the rod *i*. The steering knuckle on the right side of the automobile is exactly the same as that shown in Fig. 18, except that the arm *c* is omitted.

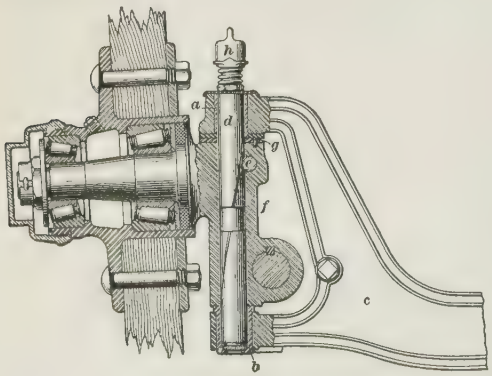

FIG. 19

30. A typical Elliott steering knuckle of the plain thrust-bearing type is shown partly in section in Fig. 19, the view being taken from the front of the car, looking toward the rear. The upper and lower steering-knuckle bushings *a*, *b* are made of hardened steel and are pressed in the yoke ends of the axle

center c; the pivot d is also made of hardened steel and is fastened by a tapered key e to the steering knuckle f. The load is carried on two plain hardened-steel thrust washers g, the upper one being fixed in relation to the upper yoke bearing, and the lower one being fixed by a pin in relation to the steering knuckle. A grease cup h, an oil cup, or any of the patented lubricating devices may be used for lubricating the various bearings at the yoke end of the axle center.

31. In the construction shown in Fig. 19, the pivot pin is fixed to the steering knuckle and consequently rotates with it; this construction is reversed, however, in some front axles, as for instance in that of the model T Ford car, shown in

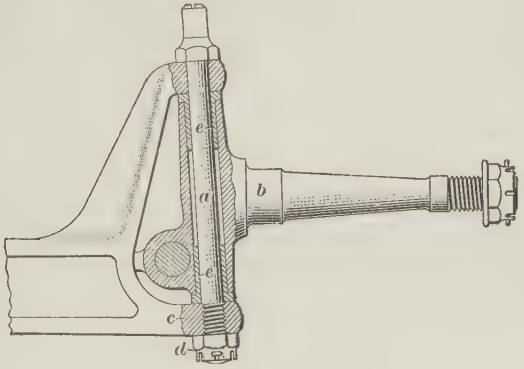

FIG. 20

Fig. 20. In this case the pivot pin a on which the steering knuckle b turns, is stationary in the yoke end of the axle center, being screwed into the lower jaw c and locked by a castellated nut d prevented by a cotter pin from unscrewing. The pivot is made of hardened steel; the steering knuckle b carries two bronze bushings e, the upper one of which, working against the soft steel of the upper jaw of the yoke, takes the thrust due to the load.

32. For the purpose of reducing the power required to turn the front wheels, the pivots of steering knuckles of many cars are fitted with antifriction bearings, either of the tapered roller or the ball thrust type. Both constructions are shown in

Fig. 21; in (*a*) a roller bearing *a* is placed in the upper jaw of the axle-center yoke, around the steering-knuckle pivot *b*. This bearing not only takes the thrust due to the load, but also sup-

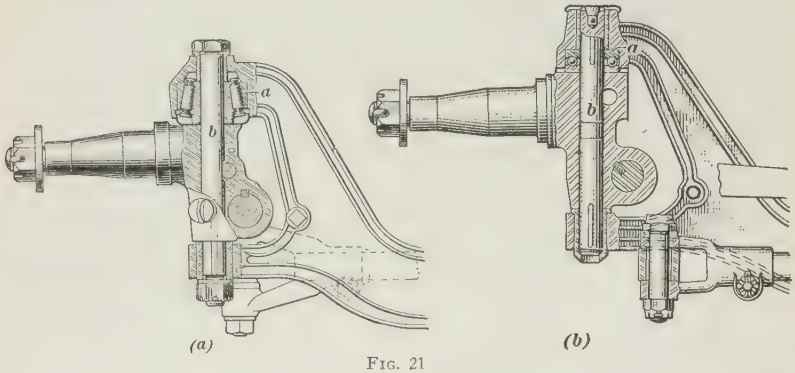

Fig. 21

ports the pivot sidewise above the steering knuckle. At the bottom the pivot *b* is supported in a plain bearing bushing of hardened steel.

In the steering knuckle shown at (*b*), the thrust due to the load is taken by a ball thrust bearing *a* placed between the upper end of the steering knuckle and in the upper jaw of the axle-center yoke. The pivot *b* is not supported sidewise by the ball bearing, but by hardened steel bushings placed in the upper and lower axle-center yoke jaws, as shown.

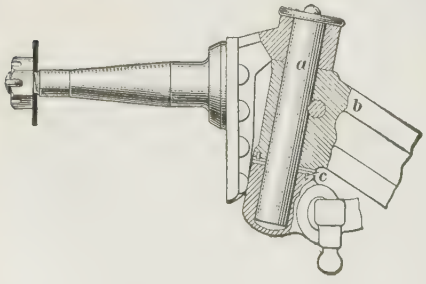

Fig. 22

33. An example of a front axle with reversed Elliott steering knuckles has been given in Fig. 17 (*b*); the left-hand steering knuckle and axle-center end of that axle is shown to an enlarged scale in Fig. 22. The steering knuckle pivot *a*, made of hardened steel, is a tight fit in the axle center end *b*.

The thrust due to the load is taken between the lower jaw of the steering knuckle and the lower surface of the end of the

axle beam, instead of at the upper end of the axle, as in the regular Elliott type. Because of this, thrust washers *c* are placed between the lower jaw of the steering knuckle and the lower surface of the end of the axle beam.

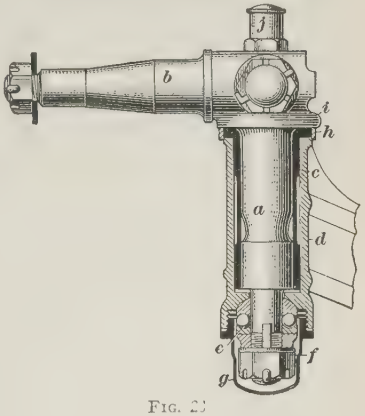

FIG. 23

34. The Lemoine steering knuckle, as used in the front axle shown in Fig. 17 (*c*), is shown in Fig. 23. The pivot *a* is in one piece with the steering-knuckle spindle *b* on which the front wheel revolves. The pivot *a* is supported by a bronze bushing *c*, carried in the end of the axle center *d*. The thrust due to the load is carried by hte ball bearing *e* and the nut *f*; the nut *f* serves also as an adjustment nut for the bearing *e*. A cap *g* that screws into the bottom of the axle end prevents oil from escaping from the bottom of the steering knuckle. The

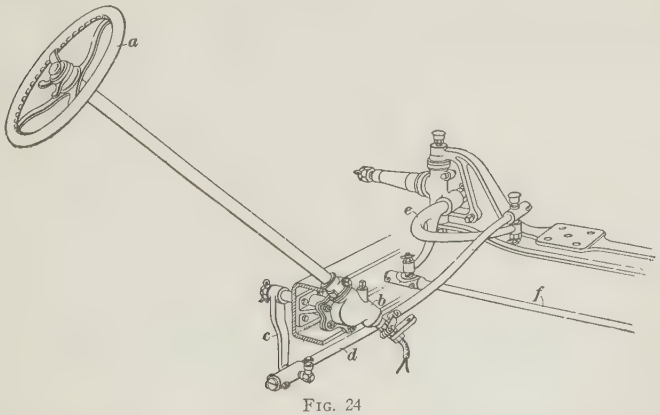

FIG. 24

space between the spindle *b* and the bushing *c* is closed at the top by a dust cap *h*, which is threaded on to the bushing, and also by a projecting shoulder *i* on the spindle. An oil

chamber is provided in the interior of the pivot *a*, which is filled, when necessary, through an oil cup *j*.

35. Steering Connections.—In Fig. 24 is illustrated the steering system of a modern automobile, with the steering gear located on the left side of the car. This system is presented to show the way in which most modern cars have the steering system arranged and how turning the steering wheel *a* to the right or left causes a corresponding movement of the front wheels and hence of the car. When the steering wheel *a* is rotated, whatever form of mechanism is employed at the base *b* of the steering column causes the steering-gear arm *c* to swing forwards or backwards in line with the length of the car, as the case may be; thus, if the steering wheel *a* is turned to the right, the steering-gear arm *c* is swung to the rear. The steering-gear connecting-rod *d* is attached to the lower end of the steering-gear arm *c* at its one end, and to the gear-rod arm *e* of the left steering knuckle at its other end; the two steering knuckles are connected by the usual tie-rod *f*, which is attached to the steering-knuckle arms. Therefore, when the steering wheel *a* is turned to the right, the backward swing of the steering-gear arm *c* causes the steering-knuckle gear-rod arm *e* to swing backwards, causing the front wheels to be turned to the right, so the car will turn to the right. Conversely, rotation of the steering wheel *a* to the left swings the front wheels to the left.

It is to be noted that on this automobile the steering wheel *a* is located on the left-hand side, so that the rod *d* and the arm *e* are also on the left-hand side. However, on most cars built for export it is customary to place the steering column on the right-hand side of the automobile, in which case the steering-gear connecting-rod and the steering-gear arm are also placed on that side. Generally, the tie-rod that connects the steering-knuckle arms is located behind the front axle, as is indicated in Fig. 24, the object being to protect it from damage that might result from obstructions in the road.

36. On a few makes of automobiles the steering-gear connecting-rod does not lie substantially parallel to the frame of the car, but lies approximately parallel to the front axle. In

that case the steering-gear arm swings to and fro across the chassis, and the steering-gear connecting-rod is connected to the steering knuckle, or to the steering-knuckle tie-rod, on the side of the car opposite that where the steering gear is located.

37. Mounting Front Wheels.—In order that an automobile may be steered easily by hand, it is desirable that the front wheels turn as nearly as possible on an exact pivot; that is, that the pivot pin be as nearly as possible in line with the point where the wheel touches the ground. This object is accomplished in modern practice by having the steering knuckles constructed so that the pivot pins are not at right angles to the spindles on which the front wheels revolve; the wheels are then inclined slightly and are closer together at the bottom than at the top. By thus bringing the bottom of the wheel as near as possible to the center line of the pivot pin, the ease with which the wheels may be turned in steering is increased.

In some cases the pivots of the steering knuckles are vertical, and in other cases they are inclined, the two pivots being farther apart at the bottom than at the top, but in either case the object is to bring the center line of the pivot as near in line with the point on which the front wheel touches the ground as is permitted by practical considerations.

In another method that has been used, ease of steering was obtained by making the hub of the front wheel hollow and placing the steering knuckle in its center. In this way, the center of the steering-knuckle pivot pin was brought into exact line with the center plane of the wheel, and maximum ease of steering was produced because the wheel turned on an exact pivot. An example of this form of steering knuckle is found on some old models of the six-cylinder Marmon car.

38. Caster Steering.—By means of certain particular settings of the steering-knuckle pivots, it is possible to make the front wheels of an automobile keep automatically in line with the rear wheels while the car is in motion, thus tending to make it go straight ahead. The principle involved is identical with that used in casters placed under furniture or a modification of it; for this reason, front axles constructed on the same prin-

ciple are known as caster steering axles. This effect is accomplished in modern practice in two ways, which are illustrated in Fig. 25.

In the first method, which is shown greatly exaggerated in view (*a*), the steering knuckle *a* is slanted so that the line *A B*, which passes through the center of the pivot pin, meets the ground at a point *b*, which is a short distance ahead of the point *c* where the tire touches the ground. It is assumed that the front of the automobile points in the direction of the arrow *x*. Slanting the steering knuckles in the manner first

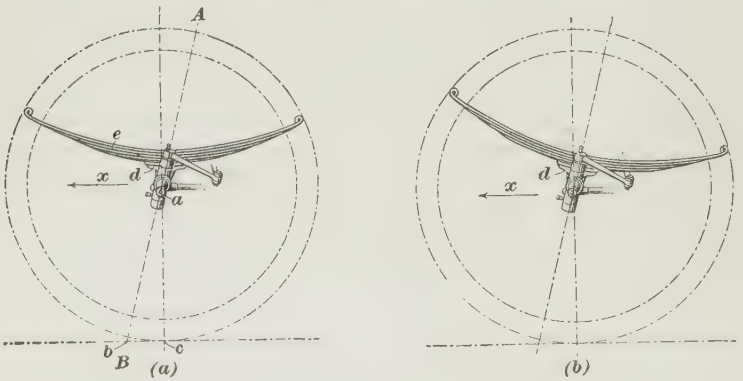

Fig. 25

explained gives the same steering effect as slanting the front fork of a bicycle; that is, the weight of the automobile tends to keep the front wheels in line with the rear wheels and to make the car go straight ahead. It is to be noted that in this case the spring seat *d* is not set square with the axle but is tilted slightly to allow the spring *c* to be mounted horizontally.

The second method is shown greatly exaggerated in view (*b*). This method resembles, somewhat, that illustrated in view (*a*), except that the spring seat *d* is set square with the pivot pin, so that both the spring and the pivot pin are tilted in order to slant the steering knuckle. In many cases the method first explained is combined with part of the second method, in that the front springs are tilted, their front end being higher than their rear end; in other words, besides mounting the springs at

an inclination to the steering pivots, as in (*a*), the axle and springs as a whole are also inclined in relation to the frame, as in (*b*).

With a caster-steering front axle of the usual method of construction, turning the front wheels to the right or left from their straight ahead position, slightly raises the front end of the car. Therefore, the weight of the car tends naturally to bring the front wheels back to their straight ahead position, thus adding to the security of the steering, as the car will tend to move straight ahead unless deliberately deflected from its course, at least on an even road free from undue obstructions.

39. Toe-In and Camber.—The front wheels of an automobile are set so as to "toe in" slightly. By this is meant that

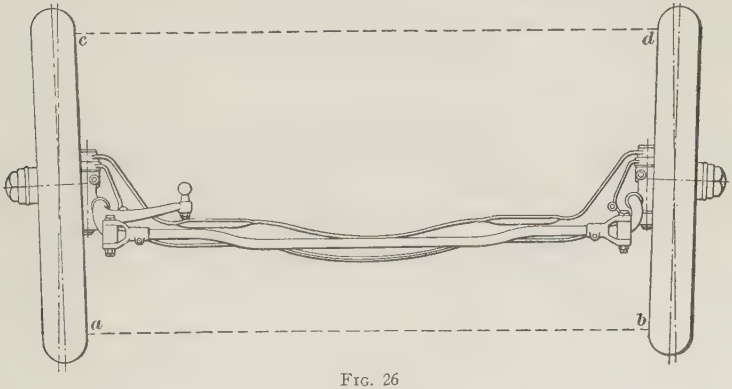

FIG. 26

when the wheels are in their straight-ahead position, there should be a difference of $\frac{1}{4}$ inch to $\frac{3}{8}$ inch in the distance between the extremities of the front wheels at the front and at the back, the wheels being closer together at the front. This measurement should be made at the same height from the floor, and between the felloes, rather than between the tires. It is easier and safer to steer a car with the wheels toeing in at the front, than one in which the wheels are straight, or toe out; that is, in which the front wheels are farther apart at the front edges.

The front wheels are also generally cambered, that is, they are set so that when in the straight-ahead position, the extreme tops of the wheels are farther apart than the bottoms. This condition, which is shown in Fig. 26, gives greater strength to the front-wheel mechanism and also helps to make the steering of the car easier. The distance *a b* measured between the felloes of the two front wheels should be $1\frac{3}{8}$ inches to 2 inches shorter than the distance *c d*.

REAR AXLES AND HOUSINGS

40. Types of Rear Axles.—Rear axles are of three general types; namely, live rear axles, dead rear axles, and the internal-gear rear axle, depending on their construction.

A *live rear axle* is one that rotates or has a rotating part. It not only carries a part of the weight of the car and the occupants, but also serves to drive the rear wheels and thus propel the vehicle.

A *dead rear axle* has no rotating parts; the wheels are driven by chains from a countershaft and they turn on spindles on the ends of the axle. A dead rear axle serves only to carry the proportionate part of the weight of the car and its load, and takes no part in driving the wheels. Dead rear axles, while at one time very popular for high-priced passenger cars, are now, broadly speaking, used only on a limited number of motor trucks.

An *internal-gear rear axle* consists of a dead axle that carries the weight of the car and a live axle that transmits the driving power to the wheels. This drive, as in the case of the chain drive, is used only on commercial vehicles.

41. All American-made automobiles at present use a live rear axle. This form of axle is made up of three principal parts; namely, a two-piece driving axle shaft, a differential, and a housing that encloses the axle shaft and the differential. That part of the housing which surrounds the axle shaft is sometimes called the axle tube, and to it are pinned and brazed or otherwise fastened, or confined in some suitable

manner, the spring seats, to which the rear springs are fastened by means of spring clips. Each half of the axle shaft is attached at its inner end to the differential, which is located in the middle of the axle, and at the outer end to one of the road wheels, which it drives. The axle shaft is driven through the differential, which consists of a set of gears so arranged that while both parts of the shaft receive power, one part may turn at a higher rate of speed than the other and thus allow the automobile to go around a corner without causing one of the wheels to slide. Usually, the differential is driven from the engine by means of a shaft and bevel gears, or, in the case of some trucks, by means of a shaft driving a worm that meshes with a worm-wheel.

Live rear axles are divided into a number of types, or classes, depending on the arrangement of the axle bearings and on the method of connecting the road wheels to the axle shaft. These classes are plain live rear axles, semifloating rear axles, three-quarter-floating rear axles, and full-floating rear axles.

42. Plain Live Rear Axles.—The first rear axle in general use was of the plain live-axle type and was driven by a chain and sprocket wheel. In this type, each part of the two-piece axle shaft is supported directly by two bearings, which are mounted between the axle shaft and the axle tube. Besides driving the rear wheels, the rotating axle shaft must carry the weight that comes on the rear axle. The plain live rear axles now employed are driven by a propeller shaft.

43. An example of a shaft-driven plain live rear axle is presented in Fig. 27, which illustrates the axle used on the Ford, model T, automobile, (*a*) being an external view and (*b*) a cross-sectional view; the two views are lettered the same, as far as possible, but are drawn to different scales. The cross-sectional view (*b*) shows part of the axle housing *a* cut away, exposing to view the axle shaft *b*, *b'* and the differential *c*. The axle shaft consists of the two halves *b* and *b'*, which are brought together at the differential, the differential side gear *d* being keyed to the end of *b* and the gear *e* to the end of *b'*. Each part of the shaft is supported by two roller bearings *f*

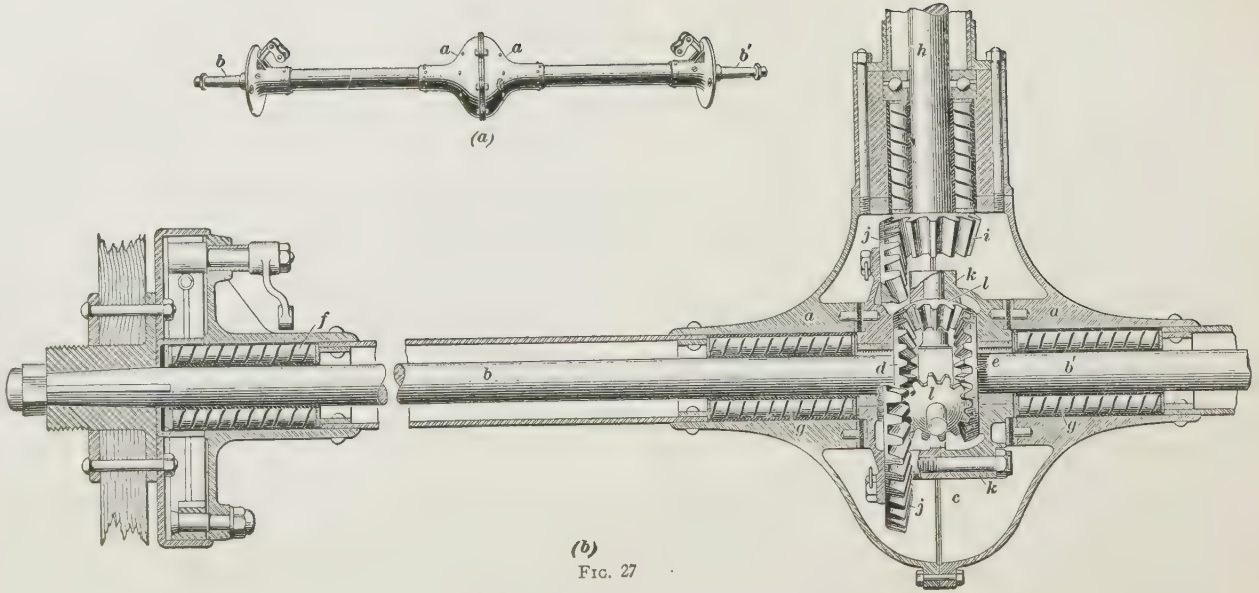

FIG. 27

and *g*. The road wheels are keyed to the outer ends of the axle shaft, which is tapered at these ends, as shown. The axle is driven from the engine through the propeller shaft *h*, which drives the differential, and, consequently, the axle shaft and road wheels, through the bevel pinion *i* and the large bevel driving gear *j*.

44. Semifloating Rear Axles.—The semifloating rear axle differs from the plain live rear axle in that the inner ends of the axle shaft are supported, that is, have a bearing, in the differential housing instead of in the axle housing. The axle shaft, at its outer ends, just as in the plain live axle, rotates directly in bearings fitted to the axle tube. The inner housing of the differential rotates on bearings that are mounted between hubs on each side of the differential housing and the outer or stationary axle housing. The axle shaft passes freely through the hubs of the housing, so that it is relieved of the weight of the differential, and its inner ends are subject chiefly to the driving stress, the axle tube taking part of the weight of the automobile. In this type of axle, the wheels are keyed or otherwise fastened to the outer ends of the axle shaft, just as in the plain live rear axle.

Owing to the fact that the inner ends of the axle shaft do not support the differential assembly, and hence are not subject to as severe bending stresses as those of the plain axle, these ends of the axle are said to float, whence the name semifloating axle is derived.

45. There is very little difference, excepting in small details of construction, between the semifloating rear axles of various automobile manufacturers, or of axle manufacturing specialists, and hence the description of one axle of this type, as shown in Fig. 28, will show the salient features common to all. The axle shaft *a* is made in two parts, as in the plain rear axle shown in Fig. 27; the two outer ends of the axle shafts are supported by the ball bearings *b*, Fig. 28, placed on the inside of the ends of the rear axle housing *c*. The whole differential *d*, including the driving gear *e* riveted to the differ-

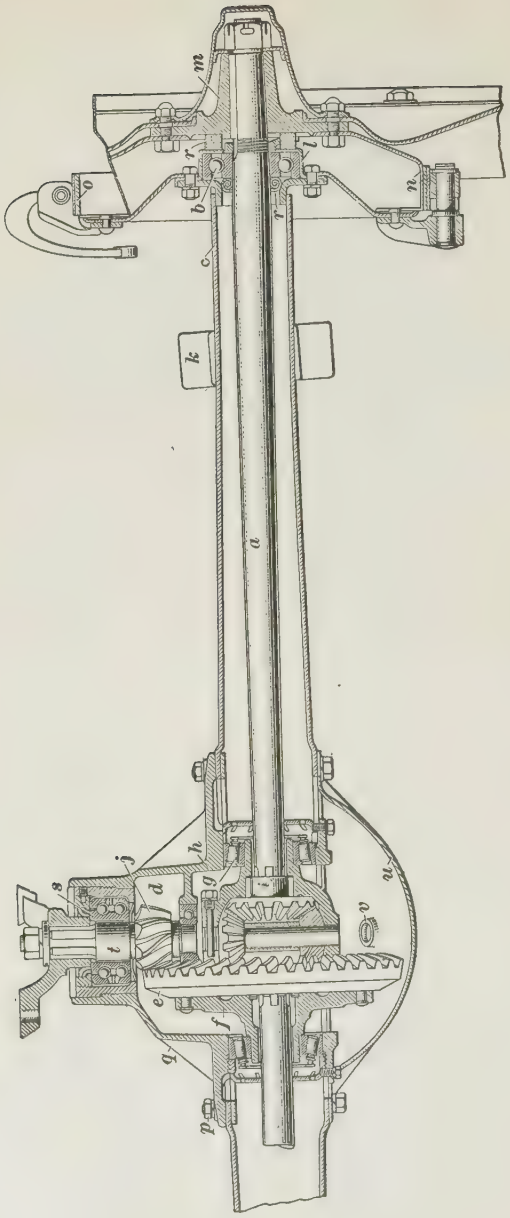

Fig. 23

ential housing *f*, instead of being carried by the axle shaft is supported by its own bearings *g*, one on each side, the bearings being placed in this case in the removable differential carrier *h*, which is bolted to the rear-axle housing. The inner ends of the halves of the axle shaft are splined, that is, have a number of rectangular keyways cut into them, and enter the correspondingly splined hubs of the differential side gears *i*, which drive the halves of the axle shaft. While the inner axle shaft ends are splined in this case, some manufacturers use squared ends entering squared holes of the differential side-gear hubs, but in neither case are the inner axle ends rigidly fastened to the differential side gears as is the case with the plain live axle. The driving pinion *j* tends to thrust the whole differential to the left; this thrust is resisted by the left bearing *g*, which being a tapered roller bearing is adapted in itself for carrying thrust loads.

The spring seats *k* of semifloating rear axles may be rigidly fastened to the axle housing, as is necessary when they are installed in a car having the Hotchkiss drive, or they may swivel on the axle housing. The two halves of the axle shaft *a*, at the particular axle shown, are prevented from coming out by the outer bearings *b* and the casing *l*, which is bolted to the housing *c*. The wheel hubs *m*, and hence the rear wheels, are fastened to the halves of the axle shaft by a taper, key, and locknut on the axle-shaft outer ends. The halves of the axle shaft can be withdrawn from the housing by first removing the rear wheels and then unbolting the cage of the outer bearings *b* from the axle housing *c*. The brake drums *n* are bolted to the rear wheel hubs, and when the whole axle is assembled, as shown, are located inside of the brake bands *o* which may be applied and released at will by the driver by means of a brake pedal. The emergency brake in the car using this axle is located on the transmission shaft.

The differential carrier *h*, together with the complete differential, can be removed as a unit from the axle housing *c* by removing the bolts *p*; a removable pressed steel cover-plate *q* gives access to the center of the rear axle for inspection purposes. The differential runs in light grease or heavy oil; this

lubricant, in the particular make and model of axle shown, is prevented from working out of the axle-housing ends by the felt oil retainers *r*.

In all bevel-gear-drive rear axles a thrust in a forward direction is exerted on the shaft that carries the bevel driving pinion. In the rear axle shown in Fig. 28 this thrust is taken care of by the double ball bearings *s* on the pinion shaft *t*; in other rear axles it is taken care of by a roller bearing, and in still others a separate thrust bearing is fitted. The differential cover-plate is shown at *u*, and the grease filling opening at *v*.

46. In order to obtain extreme quietness of operation, driving gears of the form shown in Fig. 29 are employed in

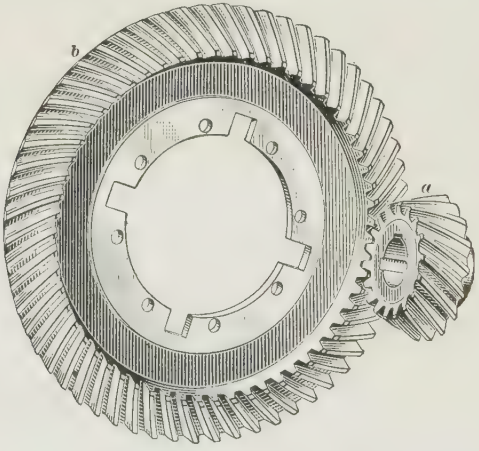

FIG. 29

practically all cars at the present time. These gears are known variously as worm bevel gears, helical bevel gears, or spiral bevel gears. When assembled in the car, the pinion *a* is keyed to the pinion shaft and the large gear *b* is fastened to the differential case. The gear-teeth of both gears are cut at an angle. The chief advantage claimed for the so-called worm-bevel drive is its quietness, which is due to the fact that there is practically no back-lash, or looseness, between the teeth with this design. One set of teeth is constantly meshing while the

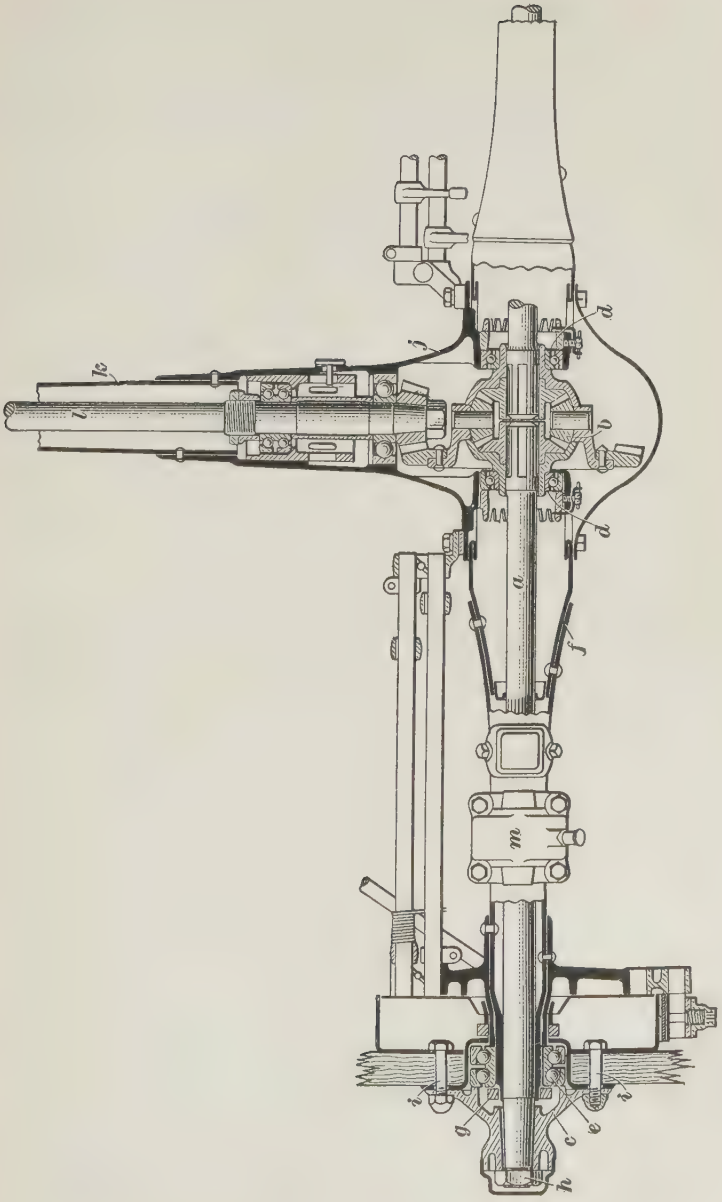

Fig. 30

next is becoming disengaged, thus affording a continuous contact.

The plain bevel gear that was so largely used at one time has now passed almost entirely out of use, being employed on only one make of car.

47. Three-Quarter-Floating Rear Axles.—In what is known as the three-quarter-floating rear axle, the bearings at the outer ends are so mounted outside of the axle tube that the wheels turn on them, and the weight of the automobile and occupants is carried by the axle tube, or housing. The axle shaft is rigidly attached to the wheels and helps to keep them in the correct position; but outside of this, broadly speaking, the only stress that comes on it is the driving stress. In this axle, the driving shaft does not come directly in contact with any bearing, but is supported at the inner ends by the differential, that is, it floats therein, and at the wheel ends it is supported by the wheels, which run on the axle tube.

Three-quarter-floating rear axles are constructed in different ways by different manufacturers and therefore naturally vary somewhat in details; thus, in some designs the halves of the axle shaft can be withdrawn from the housing without taking the wheels off or removing the whole rear axle from the car, while in other designs this operation requires removal of the wheels from the axle. In one type of three-quarter-floating rear axle, it is necessary to remove the whole rear axle and disassemble it in order to remove the axle shafts.

48. In Fig. 30 is shown, partly in section and partly in full view, the three-quarter-floating rear axle of one model of a Buick six-cylinder car. The left half of this illustration shows that part of the axle assembly cut in half, exposing to view the axle shaft and bearings, while the right half shows a top external view of a piece of the other part of the axle. At *a* is shown one-half of the axle shaft, which extends into the differential *b* at the inner end, and to which the rear-wheel hub driving flange *c* is keyed at the outer end. The differential is supported by ball bearings shown at *d*, and the wheels run in

this case each on a single double-row ball bearing, which is mounted outside of the axle tube, as at *e*. The entire weight of the load is carried by the axle housing *f*, the shaft *a* taking the driving stress and helping to keep the wheels in a vertical position. The differential is prevented from being forced endwise by flanges on the races of the bearings *d*. The rear wheels are prevented from coming off the axle housing by a locknut *g* screwed on the end of the housing, which locks the inner race of the double-row ball bearing *e* to the nousing *f*; the two outer races of each bearing *e* are confined by the rear wheel hub, and hence the rear wheels cannot come off unless the locknuts *g* are removed. Since the driving flange of the axle shaft is keyed solidly and further fastened by a nut *h* to the axle shaft, and then the driving flange is bolted by the bolts *i* to the rear wheel, the axle shafts are confined sidewise, but can be removed, without disturbing the rear wheels, by unbolting the driving flanges from the rear wheels.

In the axle here shown the differential and driving gears are mounted in a removable differential carrier *j*, which carries at its forward end the torque tube *k* surrounding the propeller shaft *l*. Since the torque as well as the driving stress is taken by the torque tube in this particular model of car, the rear springs being shackled at their front and rear ends, the spring seats *m* are loose on the axle housing.

49. Full-Floating Rear Axles.—The only difference between a full-floating rear axle and a three-quarter-floating axle is that in the former the rear wheels are not rigidly attached to the axle shaft as in the latter, but are driven from it by means of a positive clutch, or its equivalent. Two bearings are required at the outer end to support the wheel in an erect position. In this type of axle, the entire load is carried by the axle tube, or housing, while the axle shaft simply transmits the turning power from the differential to the wheels. The construction at the differential is exactly the same as in the three-quarter-floating axle or in the semifloating axle.

Full-floating rear axles are divided into two classes, which are the flange-drive and the clutch-drive axles, the two differ-

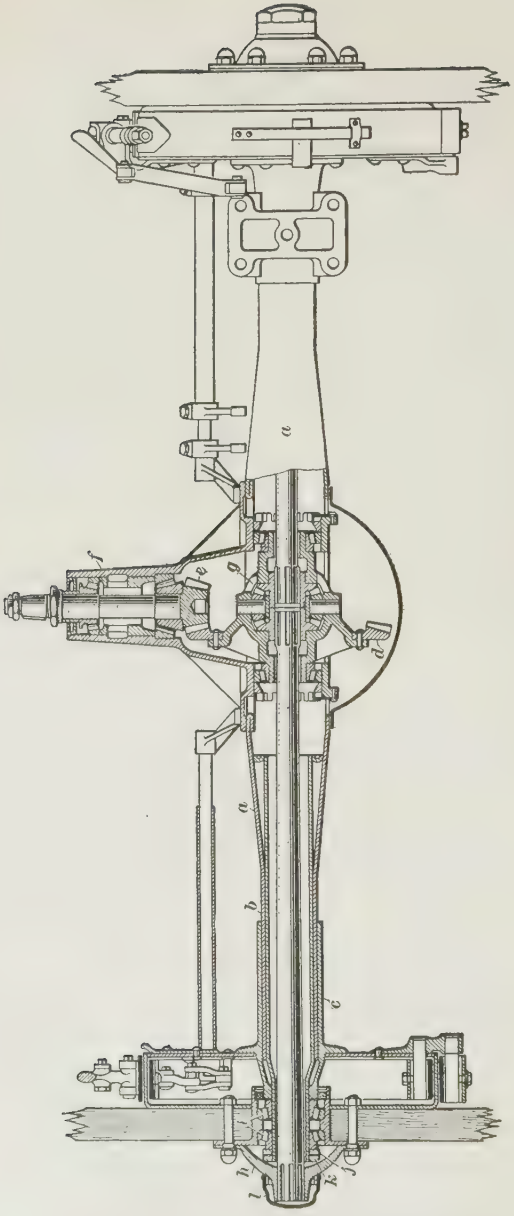

Fig. 31

ing only in the method of driving the rear wheels, which are mounted on the rear axle housing in either case so as to relieve the halves of the axle shaft from all bending stresses. The details of construction of different makes of full-floating rear axles naturally vary somewhat with different makers; thus,

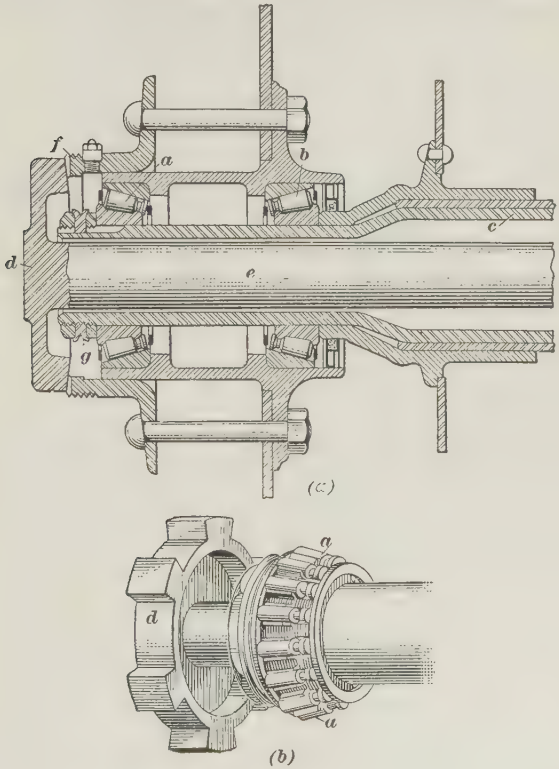

FIG. 32

where one manufacturer uses tapered roller bearings all through the axle, another maker may use ball bearings entirely, and a third manufacturer may use part ball bearings and part roller bearings.

50. A typical full-floating flange-drive rear axle is the Columbia axle shown partly in cross-section in Fig. 31. The rear axle housing *a* is made of pressed steel, reinforced at the

two ends by heavy steel tubes *b* forced in place and riveted to the housing and also to the brake supports *c*. The differential gear carrying the driving gear *d*, and the driving pinion *e* with its shaft, are mounted in a removable differential carrier *f*. The inner ends of the halves of the axle shaft are splined and float in the differential side gears *g*; the outer ends of the halves of the axle shaft are also splined and float in the driving flanges *h*, one of which is bolted to each rear wheel hub. Each rear wheel is mounted on two bearings *i*, which are adjusted by a nut *j* and locknut *k*, with a lock washer between them; each rear wheel is also kept from coming off the axle housing by the same nut, locknut, and lock washer construction. Each half of the axle shaft can be withdrawn from the housing by removing the driving flange *h* together with the hub cap *l* from the wheel. It is to be noted that in the design here shown the hub cap has no part in confining the axle shaft halves, this office being performed by the driving flanges.

51. The Timken-Detroit full-floating rear axle, the outer or wheel end of which is shown in Fig. 32, is an example of a clutch-drive axle, (*a*) being a sectional view of the wheel end, and (*b*) an outside view of the driving jaw, the bearing retaining nuts, and the outer bearing. The same parts are lettered alike in both views. The wheel runs on two bearings, *a*, *b*, view (*a*), both of which are mounted on the small part of the axle tube *c*, and is driven by the clutch *d*, which has six projecting lugs that form an integral part of the axle shaft, as shown in (*b*), and that engage slots in the wheel hub. The main-axle housing, view (*a*), is made of pressed steel and contains two inner reinforcing sleeves, or tubes *c*, one on each side; each of these helps to carry the wheel bearings at its outer end. Each rear wheel is kept in place on the axle housing by two locknuts between which is located the lock washer *g*; the halves of the axle shaft are kept in place, however, by the hub caps. Consequently, upon removing a hub cap, the half of the axle shaft it holds in place can be withdrawn.

52. Worm-Gear-Driven Rear Axles.—All the rear axles thus far described are driven from the propeller shaft by means

of a bevel pinion on the end of the shaft and a large bevel driving gear attached to the differential. Another form of drive that is used to a large extent for motor trucks is the worm-gear drive, in which the axle shaft is driven by means of a worm on the end of the propeller shaft, and a worm-wheel on the differential. The worm meshes with the worm-wheel and turns the differential, just as the bevel pinion and gear do in the more common form of axle. The worm-gear drive may, of course, be used on any type of rear axle, just the same as may the bevel-gear drive.

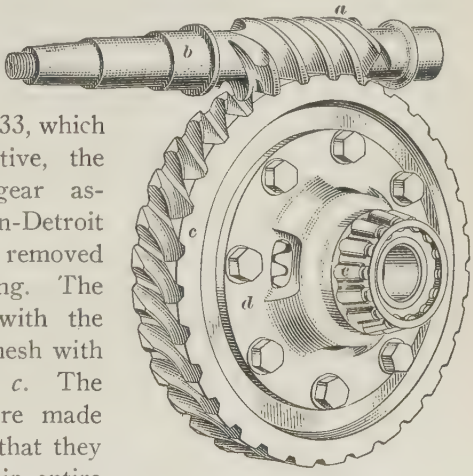

FIG. 33

An example of a worm and worm-wheel is shown in Fig. 33, which illustrates, in perspective, the complete differential-gear assembly of a Timken-Detroit worm-drive rear axle removed from the axle housing. The worm *a* is integral with the shaft *b*, and its teeth mesh with the teeth on the wheel *c*. The teeth on the wheel are made concave, as shown, so that they make contact over their entire width with the teeth on the worm. In the example illustrated, the worm is located on top of the wheel, but worm-drive rear axles are also built with the worm underneath. With the type of construction last named, the worm may run in a bath of oil. In the illustration, one part of the differential housing is shown at *d*; a hub formed thereon carries the roller bearing *e*.

53. Rear-Axle Housings.—A rear-axle housing consists, in part, of an enlarged portion, in the middle of the axle, that encloses the differential gears, and, in part, of two axle tubes that surround the two halves of the axle shaft. The enlarged part, or differential housing, is sometimes called the bridge,

and the axle tubes are sometimes known as the bridge tubes. In axle housings of the built-up type, the outer differential housing and the axle tubes are separate pieces, the differential housing being either made in two halves or provided with a large opening to permit insertion, inspection, and removal of the differential-gear assembly. The outer differential housings in the built-up type of axle housing are made of cast steel, cast bronze, cast aluminum, malleable iron, pressed steel, or drop forgings, and the tubes are usually made of drawn steel, although they are sometimes cast. The tubes are fitted to the outer differential housing in a variety of ways. In some cases, they are forced into the hubs of the housing and riveted, sometimes they are bolted to the housing, and in still other cases they are brazed.

The rear-axle housing shown in Fig. 27 is made up of two halves bolted together, the halves of the axle tube being forced into the hubs of the housing and riveted. In the axle shown in Fig. 28, for example, the tubes are riveted to the outer differential housing, but, instead of being divided into halves, this housing is provided with a large opening at the front for inserting or removing the differential, and there is also a rear opening that is ordinarily closed by a cover-plate, which is bolted on.

54. Pressed-steel rear-axle housings in which the differential housing and the axle tubes are integral are now in wide use. Such a housing is illustrated in Fig. 30. The housing is pressed in two halves from sheet steel, and the halves are welded by the oxyacetylene method, or are riveted together, or riveted and welded together. The housing has a large opening in the front and the rear for inserting or cleaning the differential and the driving-gear assembly.

The rear-axle housing constructions here given are those in common use, but other constructions have been and still are used to a limited extent.

55. Rear-Axle Gear Ratio.—In all the live rear axles so far shown, there is a fixed ratio between the speed of the propeller shaft and that of the axle shaft, the ratio being directly proportional to the number of teeth in the driving gear on the

differential to the number of teeth in the gear on the propeller shaft. This ratio is usually expressed by dividing the number of teeth in the former by the number of teeth in the latter; thus, if the gear on the differential has 55 teeth and the gear on the propeller shaft 15 teeth, the rear axle gear ratio is said to be 55 to 15, or, dividing 55 by 15, $3\frac{2}{3}$ to 1, which ratio is usually written $3\frac{2}{3}$: 1. The smaller the gear ratio, the higher the axle is said to be geared; conversely, the greater the ratio, the lower the axle is said to be geared. This apparent contradiction disappears, however, when the effect of the gearing upon the speed of the car is considered. Thus, by comparing two rear axles, one having a gear ratio of 3 : 1 and the other a ratio of 5 : 1, and wheels of equal size, it will be plain that in the first case one revolution of the propeller shaft will turn the rear wheels $\frac{1}{3}$ of a revolution, while in the second case one revolution of the propeller shaft will turn the rear wheels $\frac{1}{5}$ of a revolution. Consequently, the car with the low gear ratio will have the higher speed per revolution of the propeller shaft, and the car with the large gear ratio the lower speed. The gear ratios in actual use in rear axles range all the way from $1\frac{1}{2}$: 1 to $5\frac{1}{4}$: 1; the smallest gear ratio is only found in cars constructed purely for racing, and the largest gear ratio in cars intended to be exceptionally good hill climbers in direct drive, that is, with the transmission gears not in use. The average gear ratio now in use is approximately 4 : 1 for touring cars and $3\frac{2}{3}$: 1 for runabouts; the values here given must be distinctly understood to be merely average values.

56. Torque Tubes and Torque Arms.—The rear-axle housing of a shaft-driven automobile has a tendency to rotate in a direction opposite that in which the wheels and the axle shaft are rotating when the engine is driving the car. This is due to the action of the bevel pinion on the end of the propeller shaft; it tends to climb up around the large bevel driving gear and to carry the differential housing and axle tubes with it. When the clutch is thrown out, so that the engine is not driving the car, and the hub brakes are applied, the wheels tend to drag the axle housing around with them, because the brake

bands are supported by the housing; hence, in this case, the axle housing has a tendency to turn in the same direction that the wheels are rotating. In order to overcome the tendency of the rear-axle housing to turn, and to keep it in its correct position, torque tubes or torque arms are often employed, if the designer of the car does not care to employ the Hotchkiss drive, in which the torque, that is, the tendency of the rear-axle to turn around its own axis, is resisted by the rear springs.

When a torque tube is used, this surrounds the propeller shaft, and is firmly attached at its rear end to the rear-axle housing. The front end of the torque tube, in case of unit power plants, is sometimes attached by a ball joint to the rear of the transmission housing; in many cases the front end of the torque tube is forked, each end of the fork being hinged to a cross-member of the frame, or to the rear end of the transmission. In a few cases the torque tube is supported at its forward end directly on the propeller shaft.

57. In the Buick car, a top view of the chassis of which is shown in Fig. 4, the torque tube *62* forms a part of the axle housing *60*, and is held in permanent alinement with the rear axle by means of the strut rods *63*. The forward end of the torque tube is bolted to a spherical piece provided at the rear end of the transmission. This piece fits into a spherical socket, and all torsional and driving strains are transmitted through the rear axle and the propeller shaft with its housing to the universal joint that connects the rear axle to the rear end of the transmission.

58. Instead of a tube surrounding the propeller shaft a separate torque arm is sometimes used to prevent rotation of the rear-axle housing. This is an arm which sometimes is bolted rigidly to the rear-axle housing, and sometimes is so mounted on the housing, by means of a pin in a vertical plane, that it can swing sidewise to some extent. The forward end of the torque arm is usually hinged to a cross-member of the frame by means of a link, and consequently a torque arm thus installed cannot take the driving stress.

59. Torque arms are made in various ways; some are built up of steel tubing and fittings, while others are pressed from sheet steel, and are either solid or perforated to lighten them.

The principle of construction of a torque arm made of steel

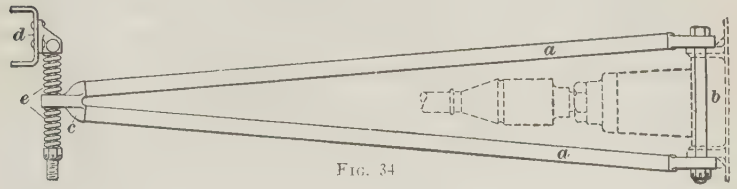

FIG. 34

tubing and fittings is shown in Fig. 34. The rear ends of the two steel tubes are attached by the long bolt *b* to the rear-axle housing, shown in dotted lines, and hence can swing sidewise, and the front ends of these rods are joined to a suitable fitting *c*. This fitting, in turn, is attached by means of a spring connection to a cross-member *d* of the frame of the car. The end of the fitting is made in the form of an eye, through which the spring bolt passes; thus, the fitting is cushioned between the springs *e*, which are suspended from *d*, and the shocks coming on the frame of the car as well as on the torque arm are by this means greatly reduced.

In many cars the fitting *c* has a ball formed at the end of it instead of an eye; this ball then fits between two sockets, each of which is backed by a spring contained in a cylindrical cas-

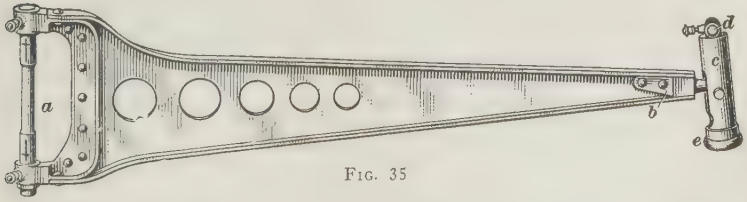

FIG. 35

ing, the upper end of which is hinged to a cross-member of the frame.

A typical pressed-steel torque arm of the perforated type is shown, removed from the car, in Fig. 35. It is attached to the rear-axle housing by the pin *a*, on which it can swivel side-

wise; the forward end *b* of the torque arm has a ball-shaped fitting riveted to it, which passes through a suitable slot of the cylindrical casing *c* hinged by a pin *d* to a frame cross-member. The cap *e* retains the upper spring and socket as well as the lower spring and socket in place in the casing *c*; the springs are made of such a length that they are compressed to some extent by screwing the cap *e* home. In some designs a threaded plug instead of a cap is used for compressing the springs.

60. Radius Rods.—In the strict sense, **radius rods** are attached at one end to the rear axle of an automobile and at the other end to the frame for the purpose of keeping the axle in alinement with the remainder of the car. These rods, one on each side of the frame of the car, are usually provided with two yoke ends, one of which is pinned to a lug carried by the spring-seat forging or by a special fitting on the axle tube, and the other to a lug on the frame, thereby permitting the axle to move freely up and down, but maintaining equal distances to the ends of the axle.

61. Diagonal brace rods, which are also commonly classed as radius rods, are used on a number of automobiles for the purpose of tying the rear axle and the torque tube together. One of these rods is located on each side of the car, and extends from the outer end of the axle tube to the forward end of the propeller-shaft housing, or torque tube, as was shown in Fig. 4. Such brace rods usually have yoke ends, and they are attached in the same manner as the true radius rods just described. This form of radius rod is not attached to the frame of the car, so it does not take the driving stress; it serves only as a stiffener, or brace, holding the axle and the torque tube in their correct relative positions.

DIFFERENTIAL GEARING

62. Differential Gears.—When an automobile turns a corner, the outer rear wheel must turn faster than the inner one, because it has a greater distance to travel; at the same time power from the engine must be transmitted to both rear wheels, even though they turn at unequal speeds. The device

universally used for this purpose is called a differential gear, and is incorporated in the rear axle. In a very few cases no differential gear of any kind has been fitted; in such cases in turning to the right or left one rear wheel slides on the ground to some extent, at least with the commonly used methods of driving cars by positive means, as by gears. A few cars have been built, and are built from time to time, in which a non-positive drive of the rear wheels is used, as for instance, by friction rollers or by belting, and the differential gear is omitted; and because of such non-positive methods of driving, one wheel can run faster than the other through slipping of the driving mechanism. This type of drive has, however, never met with

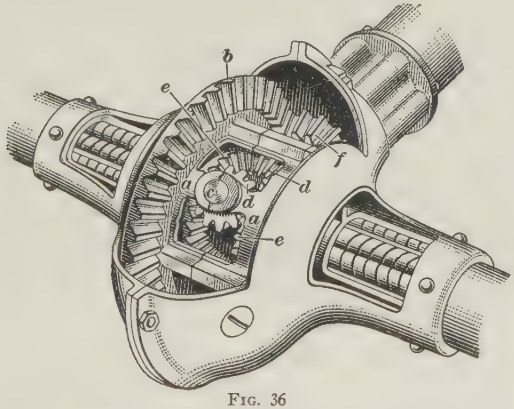

FIG. 36

popular favor, and has given way to the differential gearing now in universal use.

63. The differential gears that have been in use in past years may be divided into free gears and locked gears; of these two general types, the free differential gear is used entirely in automobiles at the present time. A free differential gear may be defined as one that leaves the two halves of the axle shaft free to turn independently of each other, even when going straight ahead. A locked differential gear may be defined as one that automatically locks the two halves of the axle shaft together when the car is going straight ahead, leaving the two halves free, however, when turning a corner. The automati-

cally locked differential gear, in spite of its advantages over the free differential gear, is not used at present in automobiles, its use being confined chiefly to heavy trucks for military work, or for heavy commercial work over very difficult roads.

64. In Fig. 36 is shown in perspective the bevel-gear type differential gear used in the model T Ford car, part of the housing being cut away to expose the gears to view. The differential gear, this title including the whole mechanism, consists, in part, of the two-part differential case *a*, to which is fastened the axle-drive bevel gear *b*, which being in the form of a ring, is often called the ring gear. The ring gear used on the Ford car is of the straight bevel type, but other cars now use the helical bevel gear. The differential case has three pinion shafts *c*, which are placed radial and equidistant, and upon which are mounted three differential pinions *d* of the bevel-gear type (only two of these can be seen in the illustration). The three bevel pinions mesh with the differential side gears *e*, one of which is keyed to the inner end of the each half of the axle shaft.

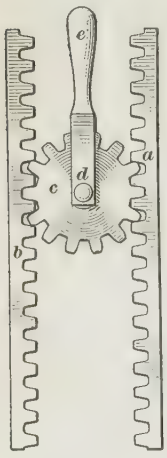

FIG. 37

65. Principle of Operation.—The principle of operation of the differential gears may be explained as follows: In Fig. 37 let *a* and *b* be two racks, that is, two straight bars with gear-teeth, that are movable in the direction of their length, and let *c* be a spur-gear mounted on a yoke *d* and having a handle *e*. Assume that both racks *a*, *b* oppose exactly the same resistance to an upward motion, and that the handle *e* is raised. Then, under the assumptions just made, the racks *a*, *b* will both move simultaneously the same distance as the gear *c*, and the latter will not turn in the yoke *d* but simply serve as a lock between the two racks, moving upwards with them. Now suppose that the rack *a* is held stationary and that the gear *c* is pulled upwards once more, the rack *b* being left free to move. Then, the gear *c* will turn in the yoke *d*, as it rolls upwards on the

rack *a*, and the gear *c* will carry the rack *b* with it at twice its own speed; a similar movement occurs if the rack *b* is held stationary and the rack *a* is left free to move. Now, assume that both racks are again left free to move, but that one of them offers a greater resistance to motion than the other; then, upon pulling the gear *c* upwards, both racks will move upwards, but at different speeds, the one offering the greatest resistance moving the slower, because under the assumed conditions the gear *c* will roll on the rack offering the greater resistance and therefore carry the other rack along at twice its own speed. Next, assume that both racks are left free to move, that the yoke *d* is kept stationary, but that the gear *c* is left free to turn in the yoke *d*. Then, if the one rack is pulled upwards, it rotates the gear *c*, and this gear in turn pushes the other rack downwards; that is, the two racks now move in opposite directions, but at the same speed.

In the differential gear, the two racks of Fig. 37 are replaced by the differential side gears, and the gear *c* by the differential pinions; the yoke *d* with its pin *e* is replaced by the differential case and its pinion shafts, and the handle *e* by the axle drive bevel gear. The operation in the actual differential gear under all conditions is identical with that described in connection with the two racks and the gear. Thus, when the car is going straight ahead, both differential side gears move forwards at the same speed, the differential pinions not rotating on their pinion shafts. Again, in turning a corner, say to the right, the right gear-wheel, and hence the right differential side gear, offers a greater resistance to motion than the left rear wheel, and consequently the differential pinions turn on their own pinion shafts, at the same time rolling on the right differential side gear, thus turning the left differential side gear, and hence the left rear wheel faster than the right, as is necessary. A similar action occurs in turning a corner to the left.

The conditions last assumed in connection with Fig. 37 do not occur in the actual driving of the car, but only when the rear axle is jacked up so that both rear wheels are clear of the ground, and the propeller shaft is rigidly held from rotating. Then, turning the one rear wheel forwards turns the

other rear wheel backwards at the same speed. If the propeller shaft is left unlocked, however, with both rear wheels jacked off the ground, the turning of one rear wheel by hand can produce several results, depending entirely upon where the frictional resistance is greatest. Thus, both wheels may turn in the same direction at the same speed or at different speeds, or one wheel may even stand still or turn backwards at differing speeds.

66. The differential gear permits independent action of the rear wheels, which very fact under certain conditions presents a disadvantage which has led to the design of numerous automatically locking differential gears, which in spite of their advantages have not come into common use, however. Thus, in driving the car it may occasionally happen that one rear wheel strikes a very greasy spot in the road while the other remains on firm ground offering a high resistance to its turning; under this condition the wheel on the greasy spot will spin, or run faster than the one on firm ground, which not only has a bad effect on the tire of the spinning wheel, but may also cause the car to slip sidewise, or *skid,* as it is called. Also, a car may run into a depression in or alongside the road in such a way that one rear wheel is perhaps clear of the ground; under this condition the car cannot pull itself out of the hole under its own power, because the one wheel remains stationary and the free wheel spins. If this happens, the car must either be pulled out, or in some way some retardation applied to the free wheel to prevent its spinning.

SPRINGS AND FRAMES

AUTOMOBILE SPRINGS

67. The springs used for supporting the frame and body of an automobile on its axles, are made up of long and comparatively thin and narrow curved steel plates, or leaves, of different lengths. These leaves are usually held together by a bolt at the center, although in some springs this bolt is elimi-

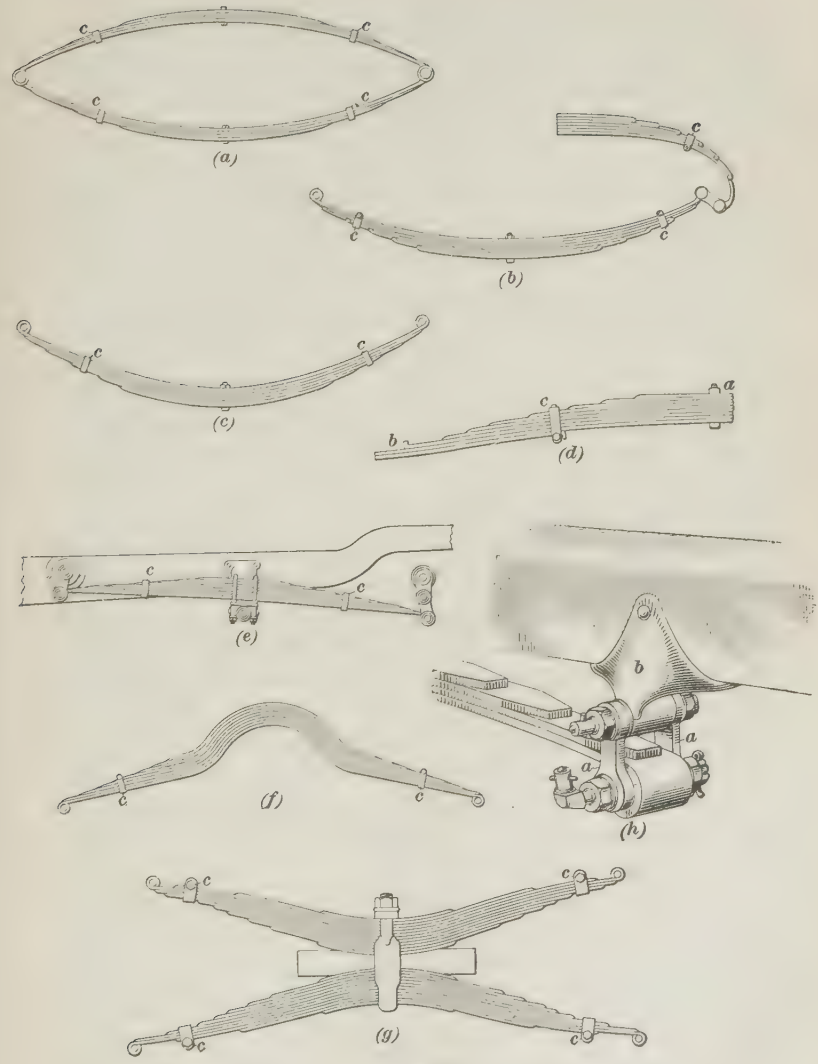

FIG. 38

nated and clips are used entirely. The shorter leaves are usually prevented from moving sidewise by small lips at their ends, by projections of one leaf entering corresponding depressions of the next leaf, or by clips that pass around them. Springs are assembled in a number of different shapes and are named according to the form in which they are made up.

68. In Fig. 38 is shown each of the most common different types of automobile springs in outline, as well as the way in which the parts are held together.

A *full-elliptic spring,* or, simply, an elliptic spring, is one in which the leaves are bent, or arched, so as to take the form of an ellipse. View (*a*) shows a common form of elliptic spring. It is composed of an upper and a lower half joined at both ends with bolts. The full-elliptic spring was very popular in the early types of automobiles, but its use today is confined to one or two makes of cars.

A *three-quarter-elliptic spring* is one composed of the bottom part and one-half of the top part of a full elliptic spring, joined either by a bolt, or by a shackle. Such a spring, in which the upper quarter is shackled to the lower half, is shown in view (*b*). This type of spring at one time was used more than any other as a rear spring on passenger cars, but is rapidly giving way in modern practice to the semielliptic spring.

A *half-elliptic spring* is simply half of a full-elliptic spring. It is called semielliptic. A spring of this type is shown in view (*c*). The semielliptic spring is sometimes used without a shackle at either end, with a shackle at one end only, or with one at each end.

In view (*d*) is shown a *quarter-elliptic spring,* which consists substantially of one-half of a semielliptic spring. The end *a* of the spring is fastened by a bracket to a side member of the frame, or is attached to the frame at the rear, while the end *b* is bolted to the spring seat on the axle housing.

What is known as a *cantilever spring* is shown in view (*e*). It consists of an inverted and very flat semielliptic spring shackled at its rear end to the rear axle and at its front end to the frame, and pivoted at its middle to the frame. The

spring may also be attached to the axle by means of a roller connection, which allows a free backward-and-forward motion. When supported in this manner, it extends underneath the axle.

A *cross-spring* is a spring that runs crosswise on the car, and therein it differs from the springs previously described, which are arranged lengthwise with the frame, with the exception of the quarter-elliptic, which is generally arranged at an angle to the frame. The single cross-spring resembles an inverted semi-elliptic spring, as will be seen in view (*f*), which shows the rear cross-spring of the model T Ford car. When in place on the car, it is shackled to lugs on the axle at both ends and supports the load at its center. A special type, known as a *double cross-spring,* is applied to some cars; it consists of two semielliptic springs placed back to back, one being attached to the rear axle and one to the frame of the car. A spring of this type is shown in view (*g*).

A shackle connection is shown in view (*h*). It consists of two side members *a* that have a bolt passing through them and the eye in the spring at one end, and through them and the bracket *b* on the frame at the other end. A flexible connection is thus made between the frame and the spring, and some provision must be made for holding the rear axle in line with the frame.

69. After a spring has been compressed, the following upward movement, or recoil, tends to cause separation of its leaves, which separation may result in their breakage. This fact is especially true of the master leaf, which is that leaf on the ends of which are formed the eyes for attaching it to the frame of the car, to the shackles, or to the other part of the spring in case of other than the half-elliptic spring. To reduce this danger of spring breakage through recoil, many springs are now fitted with recoil clips, which are narrow clips that surround several spring leaves and the master leaf, and that permit free sliding of the leaves on each other while restraining their separation. Such recoil clips are shown at *c* in the different springs shown in Fig. 38.

SHOCK ABSORBERS

70. Devices that are used to modify the action of automobile springs and thus prevent excessive vibration of the body of the car while passing over rough roads are called *shock absorbers*. These devices are attached to the frame and the springs or axles, so that they offer resistance to the action of the springs and tend to do away with any jar when the springs are suddenly compressed, or when they recoil. There are three general types of shock absorbers, which may be classified as follows according to the method used to obtain the required resistance: (1) those which depend on the frictional resistance of two or more surfaces in contact; (2) those which depend on restricting the flow of a fluid; and (3) those which depend on the action of some kind of supplementary springs.

Shock absorbers are also classified according to the type of tires with which they are to be used, being known as regular-type shock absorbers, and balloon-type shock absorbers.

AUTOMOBILE FRAMES

71. Types of Frames.—The frame is that part of an automobile that supports the body and machinery of the car; the frame rests on the springs. With regard to the material of which they are built, frames used on passenger cars are of two kinds; namely, pressed-steel frames and wooden frames. Pressed-steel frames are used almost exclusively, wooden frames being used on only one make of car at the present time. Where the wooden frame is used, it is armored with steel plates and laminated, that is, made up of several layers or laminations.

72. Wooden Frame.—The wooden frame used on the Franklin car, which is the only remaining exponent of this type of frame, is made of three laminations of second-growth white ash with a thin strip of wood placed on top of the sills to prevent water from working between the laminations. The whole is glued solidly together, and is strengthened by a steel plate bolted to it.

The wooden sills of the Franklin car are shown in Fig. 39, the side sills being shown at *a* and the rear sill at *b*. At *c* is shown the sill angle iron, which forms the engine support; a

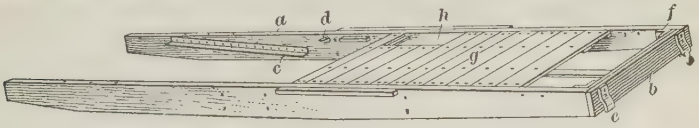

FIG. 39

similar support is provided on the inside of the opposite sill. At *d* is shown one of the brackets for the toe board, and the gasoline-tank support clips are shown at *e*. One of the braces for the rear sill is shown at *f*, a similar brace being located in the opposite corner. The floor boards are shown at *g* and the battery opening at *b*.

73. Pressed-Steel Frames.—Pressed-steel frames are made up of parts pressed, or formed, to the required shape by hydraulic presses. The longitudinal sills, or side rails, running

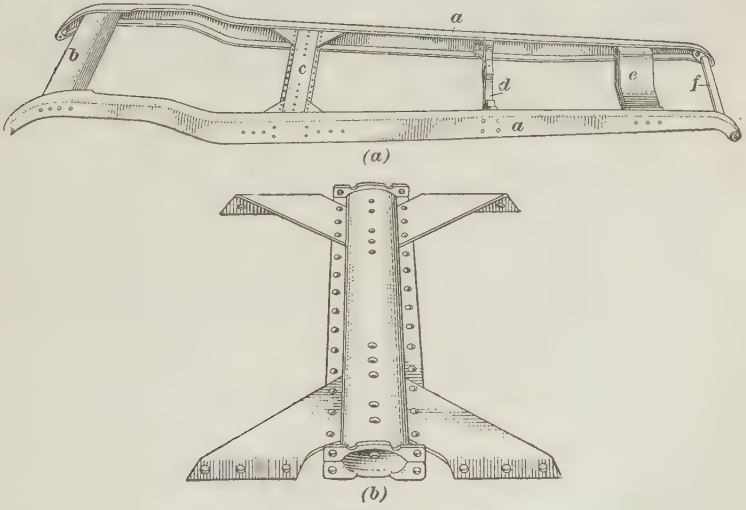

FIG. 40

lengthwise on the car, are made in channel sections, and the cross-members, running from one side to the other, are largely made in the same shapes.

A typical pressed-steel frame is shown in Fig. 40 (*a*). It consists of two side members *a* having a channel section, which are tied together by the various cross-members *b, c, d, e,* and *f,* securely attached to them by hot riveting, or in some rare cases by welding. The two cross-members, *c* and *f,* in this particular case, are tubular, the construction of member *c* being shown clearly in view (*b*). The frame is often stiffened by gusset plates riveted both to the cross-members and the side members.

As clearly shown, the side members *a* are raised over the rear axles in order to give plenty of clearance and yet permit the body of the car to be brought closer to the ground than is possible with straight side members; a frame thus offset vertically is said to be upswept or kicked up, and when kicked up at both ends is spoken of as a double kicked-up frame. Many frames are also offset horizontally in front, or narrowed, in

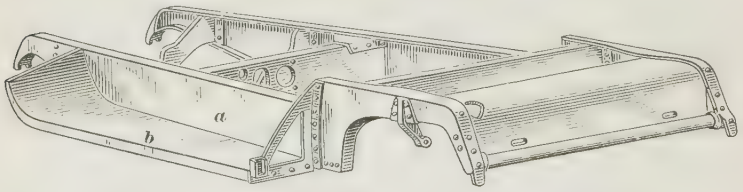

FIG. 41

order to give a larger turning radius to the front wheels, which means a shorter turning radius for the car; such a frame as the one shown is said to be inswept at the front.

74. The pressed steel frames so far shown require brackets for the running boards, but some frames are in use in which the running boards are of steel and riveted directly to the frame, which, then, instead of a channel section, has a **I** section. Such a frame, as used on the Marmon car, is shown in Fig. 41. The side members *a* are flanged inwards on top but have no flange at the bottom; they are 10 inches deep in the central part. The running boards *b* have a channel section, the flanges pointing downwards, and are hot-riveted to the lower edge of the frame side members *a,* and the ends of the running boards are curved up to meet the fenders, which here are not shown.

AUTOMOBILE-ENGINE AUXILIARIES

COOLING, MUFFLING, AND GOVERNING

COOLING SYSTEMS

INTRODUCTION

1. In an internal-combustion engine, unless provision is made for cooling, the heat from the explosion of the charge will raise the temperature of the cylinder walls and piston so high as to render lubrication impossible. The devices employed for cooling purposes comprise what is known as the **cooling system** of the automobile.

Most automobile engines are cooled by circulating water through the space between the outer wall of the cylinder and a jacket casing that surrounds the cylinder-head and the part of the cylinder barrel nearest the head. Air is used for cooling in only a comparatively small proportion of automobile engines; in fact, in American practice, air cooling is virtually limited, at the time of writing, to a single make of automobile. However, it is the standard practice to employ air cooling for the engines of motor cycles.

An objection frequently urged by advocates of air cooling to the use of water for cooling is its liability to freeze in cold weather and thereby seriously damage the engine and other parts of the power plant. This is a valid objection if only ordinary water is used; however, freezing of the water even

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at temperatures considerably below 0° F. is easily prevented by mixing with the water one or more of various inexpensive substances that have the property of greatly lowering the freezing point of the mixture.

An advantage of air cooling over water cooling is that it permits the use of a higher working temperature of the engine cylinders, which produces a better economy in the use of fuel; in a water-cooled engine the working temperature obviously can never be higher than the boiling point of water. In fact, practice has shown that a cooling-water temperature about 30° F. below the boiling point has proved in general the most satisfactory temperature; if the water temperature drops much below this point, the fuel economy drops as well, while if the temperature rises much above this point the water supply needs replenishment frequently. Another advantage of air cooling is that it greatly reduces the number of parts in the power plant of the automobile and also reduces the weight, compared with a water-cooled power plant. However, in spite of their advantages, air-cooled engines are but little used in automobiles.

2. When water is used for cooling, it enters the jacket space generally either at its lowest part or just below the exhaust valve, and flows out at the highest part. It is extremely important to have the water flow from the highest part of the jacket space, because an air pocket or steam pocket would be formed if a part of the enclosed space were higher than the outlet. It is also very important that the jacket space should be shaped so that there is no part from which the water cannot flow upwards toward the outlet.

The hot water from the jacket passes through connecting pipes to a *radiator,* where it is cooled, and from the radiator it passes back to the jacket space of the engine again. It then repeats its cycle of cooling the engine and being cooled in the radiator. Circulation is maintained either by a pump, which forces the water through the system, and which on this account is called a *forced-circulation system,* or by what is known as *thermal circulation,* which means circulation due to the heating of the water.

WATER COOLING

3. Forced-Circulation Cooling System.—In Fig. 1 is shown the water-cooling system of the Dodge car, which system serves well to illustrate the typical arrangement of the cooling-system parts in automobiles using cylinders cast in block and having the engine at the forward end of the car, as is now the universal practice. The cooling water passes from the top of the water-jacket *a* surrounding the upper end of the four cylinders through a flexible hose connection *b* to the upper tank *c* of the radiator; it then passes downwards through the tubes of

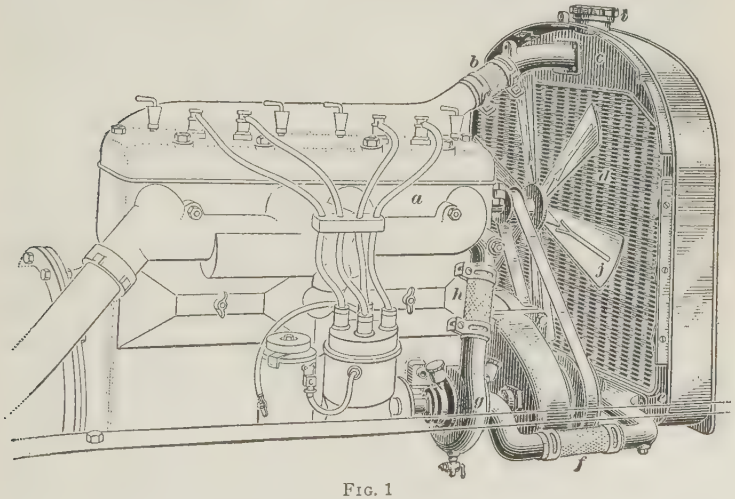

FIG. 1

the radiator *d*, which are surrounded by horizontal fins soldered to them, to the bottom tank *e* of the radiator. This bottom tank *e* is connected by a flexible hose connection *f* to the casing of the circulating pump *g*, which pump is driven from the engine and delivers the cooling water through the hose connection *h* to the bottom of the water-jacket. The water system of a water-cooled engine is filled through an opening on top of the radiator, and this opening, when not in use, is closed by a filler cap, as shown at *i*. The fan *j*, which is rotated at a high speed by the engine, draws air over the tubes of the radiator

and their surrounding fins, thereby abstracting heat from the cooling water, that is, cooling it.

4. With an engine having cylinders cast in block, as shown in Fig. 1, a single outlet from the top of the water-jacket is sufficient. When the engine has individual cylinders or twin cylinders or triple cylinders, there must be a manifold with a branch to each cylinder casting to convey the cooling water to the bottom of the water-jackets, and another manifold with branches to convey the water from the top of the water-jackets.

With eight-cylinder and twelve-cylinder **V**-type engines, where with few exceptions each cylinder group is cast in block, each group may have its own top and bottom water connections to the radiator, or a manifold may be used for the bottom and top of the cylinder water-jackets with a single top and bottom connection to the radiator. When forced circulation is employed, a separate pump may be used for each cylinder block, there being either one pump on each side of the engine or both pumps at one side, or a single pump may serve both cylinder blocks. All of these methods are used in practice.

5. Fig. 2 illustrates the cooling system employed in the Packard "Twin Six," fitted with a twelve-cylinder **V**-type engine. In this engine each group of cylinders is cast in block; part of the water-jacket of the right-hand cylinder group is shown cut away to show the water passages clearly. The tops of the water-jackets are united by a manifold *a*, which surrounds the intake manifold for the carbureter in order to heat this; at the top of the manifold *a* there is a branch *b* leading forwards and connected by a flexible hose *c* to the top tank of the radiator *d*. The bottom tank of the radiator is connected by a flexible hose *e* and pipe to the inlet side of two circulating pumps *f*, *g* placed side by side in a single pump casing. The circulating pump *f* discharges through the manifold *h* into the bottom of the water-jacket of the right-hand cylinder block; the pump *g* discharges, through a passage in the crankcase, into a manifold similar to *h* and thence into the bottom of the water-jacket of the left-hand cylinder block.

6. In the Packard cooling system shown in Fig. 2 provision is made for raising the cooling water in the water-jackets quickly to a high temperature by providing a by-pass pipe *i* connecting the top and bottom radiator connections. The opening of this by-pass pipe is controlled by an automatic valve inside the casing *j*; this valve, which is operated by the heat of the cooling water, is called a *thermostat*. With the engine cold, the by-pass *i* is wide open, and when the engine is fired,

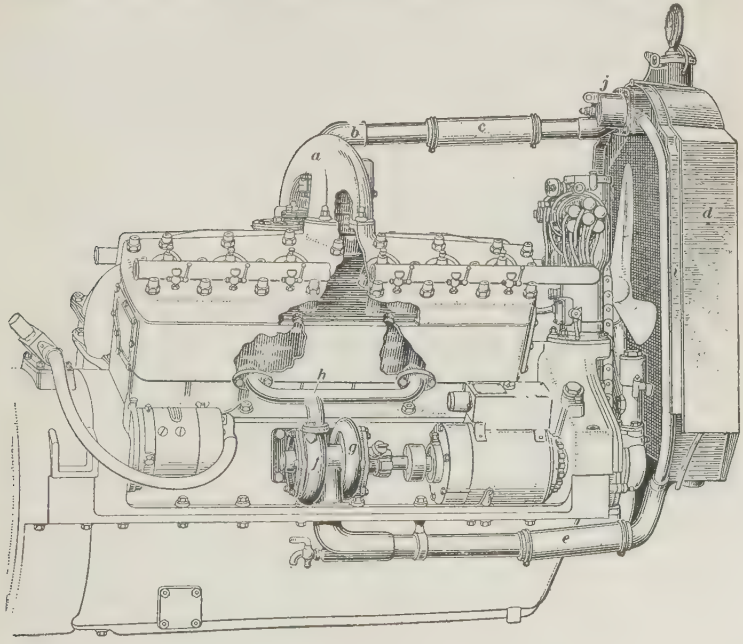

FIG. 2

the water circulation is from the circulating pumps through the water-jackets through the by-pass pipe back to the pumps, the radiator being now cut out of the cooling system. As only a small quantity of water is circulating, this heats quickly; the heating of the cooling water operates the thermostat, which closes the by-pass more and more until when the proper cooling-water temperature is reached, the by-pass is closed entirely and all cooling water now passes through the radiator. If the water drops in temperature, the thermostat will open the by-

pass again until the water is heated once more; it is thus seen that the thermostat not only insures a quick heating of the cooling water but also tends to maintain it at a uniform temperature.

A thermostatically controlled by-pass is at present used in a number of cars.

In Cadillac eight-cylinder cars there is a separate water-pump on each side of the engine; a thermostat controlling a by-pass is mounted directly on each circulating-pump casing.

7. Thermo-Siphon Cooling Systems.—Although most automobile manufacturers seem to prefer to use the forced-

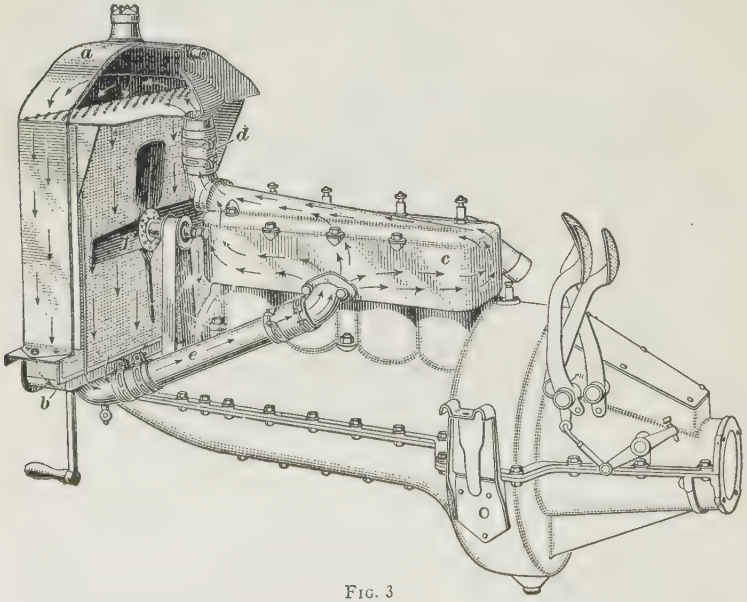

FIG. 3

circulation system of water cooling, there are some who use successfully the thermal system, or, as it is better known, the *thermo-siphon system of water cooling*. This cooling system is characterized by the absence of a circulating pump, the circulation being established and maintained by heating the water to a higher temperature in the water-jacket of the cylinders than in the remainder of the cooling system. Inasmuch as

hot water is lighter than cold water, it tends to flow upwards; conversely, cold water is heavier than hot water and tends to flow downwards.

The most widely known example of a thermo-siphon cooling system is found in all Ford, model T, cars having a manufacturer's number higher than 2,500. Cars of this model bearing a lower number were fitted with a forced-circulation system.

The radiator consists of an upper tank *a*, Fig. 3, and a lower tank *b* united by a large number of vertical tubes supplied with horizontal cooling fins. The water-jacket *c* surrounds the upper part of the four cylinders, which, together with the upper half of the crankcase, are cast in block. The heated water passes from the water-jacket, as shown by arrows, through the rubber-hose connection *d* to the upper tank *a* of the radiator, flows downward through the vertical tubes, where it is cooled by air passing over them, and drops into the bottom tank *b*, whence it flows upwards again through the hose connection *e* to the bottom of the water-jacket, taking the place of the heated water that flowed from the top of the water-jacket. A fan *f* located behind the radiator and driven by the engine draws air rapidly over the radiator tubes and thus assists the cooling of the water.

8. In the thermo-siphon cooling system employed in the Renault car the radiator, instead of being placed on the chassis in front of the engine, is mounted back of the engine; that is, just in front of the dashboard. Three views of the Renault cooling system are shown in diagrammatic form in Fig. 4. The radiator *a* consists of the usual top and bottom tanks, which are united by numerous plain vertical tubes. The top of the cylinder water-jackets is connected to the top radiator tank by the manifold *b*; the bottom of the water-jackets is connected by the manifold *c* to the bottom radiator tank. Circulation of the cooling water is established and maintained in the manner explained in Art. **7**. The engine is enclosed by the hood *d*, which has sloping sides and a sloping top and front; this hood extends backward to the radiator. The bottom of the engine

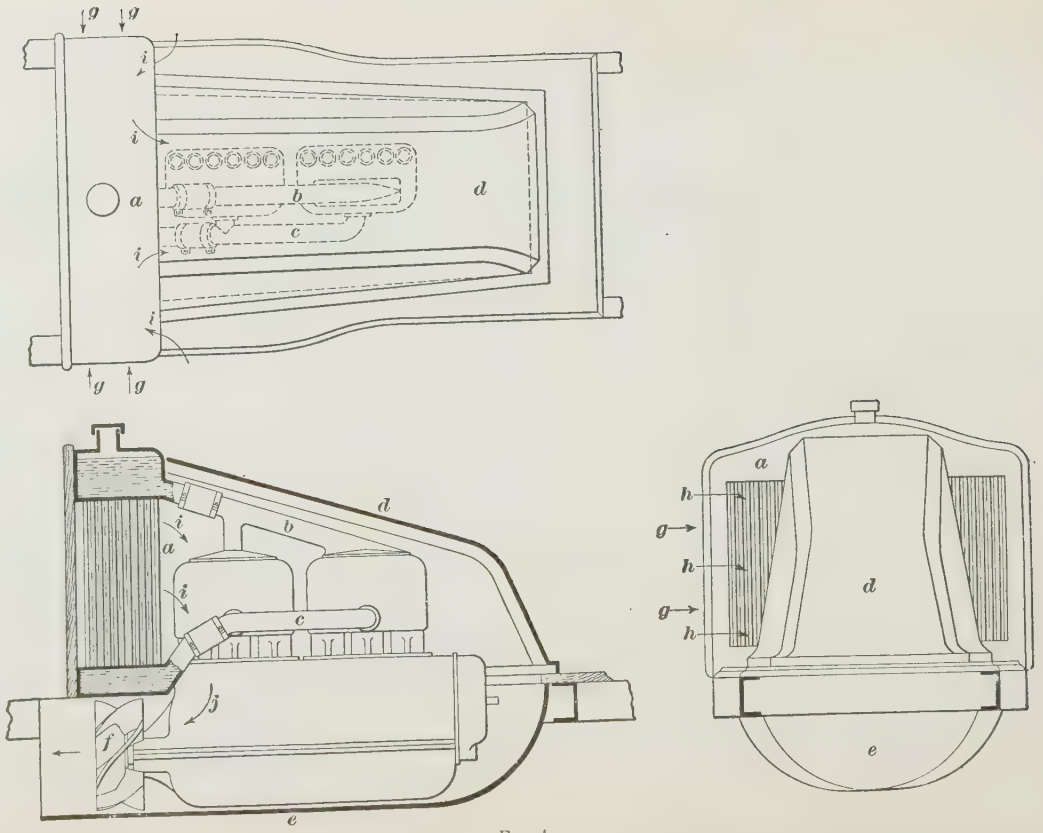

FIG. 4

is protected by the sod pan *e*, which, like the hood, is closed at the front end and open at the rear. No separate fan is employed to draw air through the radiator; the flywheel *f*, however, is cast with vanes on its outside, and these drive air to the rear. The circulation of air through the radiator is as follows: Air enters at the sides of the radiator, as shown by the arrows *g*, and also at the front through the part of the radiator that is not covered by the hood *d*, as shown by the arrows *h*. This air passes from both sides of the radiator toward the central part covered by the hood and then forwards under the hood, as shown by the arrows *i*; the air then passes downwards under the hood, as shown by the arrows *j*, past the flywheel, and out at the rear of the sod pan, the circulation being kept up by the vanes of the flywheel.

9. In a thermo-siphon cooling system, the opening through which the water from the engine enters the upper radiator tank should not be located above its bottom. If this is done, the circulation will stop as soon as the level of the water falls below the bottom of the opening, even if a considerable amount of water is still retained in the tank and the upper ends of the cooling tubes are covered with water to a considerable depth. The proper place to connect the pipe coming from the top of the water-jacket is at the bottom of the upper tank, as shown in Fig. 3.

An engine designed for pump circulation cannot be readily changed over to thermo-siphon cooling, as the latter system requires very large water passages for its successful operation. A thermo-siphon cooling system can, however, sometimes be changed over to a forced-circulation system by adding a circulating pump; such pumps for attachment to Ford cars are regularly marketed.

Thermo-siphon cooling is used not only on vertical but also on **V**-type automobile engines.

In all cases, the cooling system should not be air-tight, but should have an orifice or, *overflow*, above the normal level of the water to allow the escape of air, water, or steam. The water expands by heating, and steam is formed in case it boils.

10. Types of Radiators.—As previously explained, the cooling water heated in the water-jackets of the engine is cooled by passing it through a radiator. In order to cool the water effectually, radiators are usually made of thin metal, with as much surface exposed to the air as possible, and they are arranged so that the air can circulate through them easily.

There are two general types of radiators, which are named in accordance with their construction. One of these types is spoken of as the *tubular radiator,* the cooling being done by passing the heated water through round or flat tubes around which air circulates to abstract heat and carry it away. The second type is known as the *cellular radiator,* from the general resemblance it bears to a mass of cells; in this type of radiator the water to be cooled surrounds the cells and the air that abstracts and carries away heat passes through the cells.

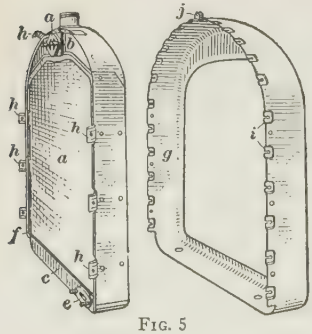

FIG. 5

Radiators are always mounted at right angles to the frame of the car, and usually in front of the engine, although some makers have mounted them at the rear of it. As a general rule, radiators are flat, but in some cases radiators, when viewed from above, are **V**-shaped, with the apex to the front, or are slightly rounded; such constructions are adopted only in order to give a distinctive appearance to the front of the car.

11. Broadly speaking, all modern radiators consist of two headers or tanks, one at the top and one at the bottom, joined either by vertical tubes with air spaces between them, or joined by water passages formed in some suitable manner to be the equivalent of vertical tubes. Radiators with horizontal tubes are obsolete. It was formerly the practice to make the tanks of highly-polished brass or German silver. The modern practice in passenger cars and many trucks is to place a shell, usually pressed from sheet steel of fairly heavy gauge, or some-

times cast from aluminum, over the assembly of tanks and separate water spaces, the latter being spoken of as the *radiator core*. The shell then serves to support the radiator on the frame of the car and also supports the front end of the hood over the engine. This construction is shown in Fig. 5, where *a* is the radiator core, *b* the top tank, *c* the bottom tank, *d* the water inlet from the top of the water-jacket of the engine, *e* the water outlet to the bottom of the cylinder water-jacket (by way of the circulating pump in case of forced water circulation), and *f* the overflow pipe. The shell *g*, which is entirely separate, is in this case pressed to shape from a single sheet of steel, and is slipped bodily over the core and tank assembly, to which it is fastened in the case shown by screws passing through the lugs, or brackets, *h*. The shell in this case is provided with pockets *i*, in which are fastened silencer pads of leather or some asbestos brake-lining fabric; the hood, the top hinge of which is supported by the hood support *j*, then rests on the silencer pads. Some variations of this shell construction are in use. Thus, in many cases, around the top and sides of the shell there is formed a distinct ledge about $\frac{3}{4}$ inch wide and $\frac{3}{16}$ inch deep, and to this ledge are attached silencer strips of leather or fabric, often in one continuous piece, on which the hood is supported.

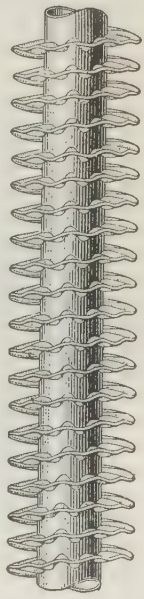

FIG. 6

By placing the radiator core and tanks inside a shell, substantially as shown, they are greatly protected from injury by vibration and by twisting of the car frame. Furthermore, the shell, being separated some distance from the tanks and core, does not get hot enough to spoil the finish, which may be enamel baked on, or regular paint and varnish.

12. Tubular-Radiator Construction.—Tubular radiators nearly always have the tubes surrounded by a large number of thin fins, or gills, that are soldered to them, the object of these fins being to increase the radiating surface.

Radiators of the tubular type may be divided into two general classes; namely, (1) radiators in which each tube has its own fins, and (2) radiators in which the fins are common to all the tubes. At one time radiators belonging to the first class were very extensively used, but of late years radiators of the second class have displaced them to a large extent in passenger-car work. For motor-truck work, however, radiators of the first class mentioned are very popular.

The *Long helically wound radiator tube* is today a widely used form of tube carrying its own fins; its construction is shown in Fig. 6. In this radiator tube, the fin is continuous, being formed from a flat strip of copper that is crimped in such a manner that it can be wound spirally around the central tube, as shown.

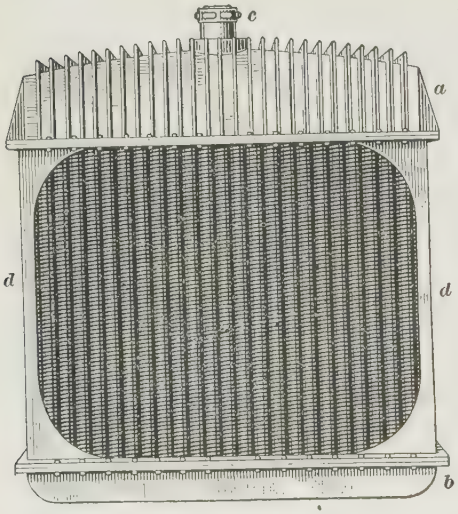

FIG. 7

13. Radiators having tubes with individual fins were at one time made up in the form of coils, the tubes running horizontally and being connected by return bends in such a manner as to form a continuous tube, with the cooling water entering at one end and leaving at the other. This method of construction is obsolete, however.

In modern practice, when tubes with individual fins are employed, the tubes are placed vertically between a top and a bottom water tank and each tube is independent of the other. The appearance of such a radiator is shown in Fig. 7, which has helically wound tubing, and is used in trucks. In this illustration, the top water tank *a* and the bottom water tank *b* are castings. The filler opening, which has a removable cap *c*, is

used for filling the cooling system with water. The top and bottom tanks are firmly tied together by the side pieces *d*. A water inlet at the top and a water outlet at the bottom are provided at the rear of the radiator, and the radiator is supported by its bottom tank, which rests on a cross member of the frame, to which it is bolted. The two side pieces *d* do not form water spaces, the water circulation being entirely through the tubes, over which the air is drawn by the usual cooling fan. The upper header is ribbed, as shown, to assist in the cooling. A water-tight joint where tubes enter the top and bottom tanks is made by soft rubber packing, or by some other suitable material.

14. The general assembly of radiator tubes with fins common to all tubes is shown in Fig. 8, which represents a small section cut from a radiator. The tubes *a* are usually from $\frac{1}{4}$ to $\frac{5}{16}$ inch in outside diameter and are vertical; they are spaced approximately 1 inch from center to center lengthwise of the radiator and $1\frac{1}{4}$ inches from center to center crosswise. The fins *b* are placed horizontal; each fin is made from flat stock with holes punched therein to fit the tubes *a*, and of a length sufficient to reach from the left to the right side of the radiator. Although circular tubes are shown in Fig. 8, some manufacturers use flat tubes, placing the narrow side forwards.

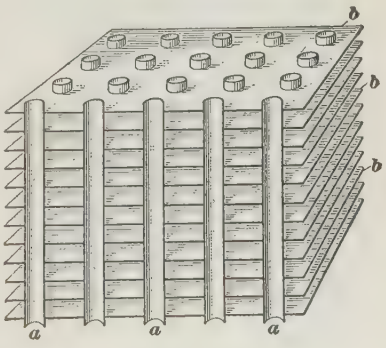

FIG. 8

In order that the fins may assist in cooling, they must be in intimate metallic contact with the tubes; to insure this contact, they are soldered to the tubes.

The general appearance of a radiator built up of vertical tubes with horizontal fins common to all the tubes is shown in Fig. 9, where *a* is the removable radiator shell, *b*, *b* are the radiator support brackets resting on the side members of the frame and bolted thereto, *c* is the filler opening closed by a

removable cap, and *d* is a hole through which passes the hand starting crank when this is to be used.

15. A water-tight joint between the tanks and tubes is made in most cases by soldering; sheet brass, sheet copper, or heavy sheet tin is used for the radiator tanks in passenger cars and in much truck work, with all joints made water-tight by soldering. The tubes and fins are also made of copper or brass, although tin plate, which is sheet steel covered with tin, is also used occasionally for fins. The whole radiator core in both tubular and cellular radiators is painted a dull black color, experiments having shown that the cooling efficiency of a radiator is greatest when this color is used. The radiator shell is painted or enameled any color that harmonizes with the general color scheme of the car.

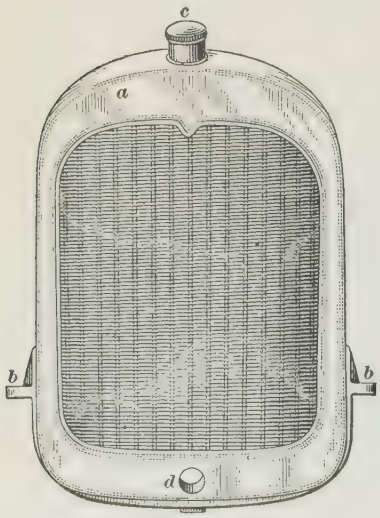

FIG. 9

16. A tubular radiator in which a comparatively small number of flat vertical tubes are used is shown cut open in Fig. 10. The tubes *a* are placed with their narrow sides to the front and the rear, and are soldered into the bottom of the top tank *b* and into the top of the bottom tank *c*. The tubes form the water passages in which the water passes downwards, air circulating around them. The two sides of the radiator, as *d*, for instance, do not form water passages. A nozzle *e* is attached to the rear of the top tank and is connected to the pipe leading to the top of the engine-cylinder water-jackets. In some cases the tubes are left plain; in other cases, fins of various kinds are soldered to the tubes in order to increase their radiating surface. One way in which the surface is extended is shown at *f*, a flat strip of sheet metal is punched

and corrugated, as shown, and is soldered to one or both sides of the tubes. The corrugated strips then extend the whole length of the tubes. Sometimes a false front, made as indicated at *g*, is fitted into the front end of the radiator in order to convey the impression that the radiator belongs to the cellular type, which is a far more expensive form.

An angle *h* made of sheet metal is usually attached to the rear of the top tank and to the rear of the two sides, forming a ledge for the hood over the engine; this angle is known as a *hood ledge*. To prevent rattling of the hood on the hood ledge, this ledge is usually perforated and a strip of rawhide belt lacing or some similar material is fastened to its outside. An overflow pipe, whose opening is at *i*, is usually attached to the upper tank and led along the back of the radiator to a point below the upper end of the lower tank; its lower end is open. This overflow pipe prevents filling the radiator too full, provides for free expansion of the cooling water on becoming heated, and prevents an accumulation of pressure in the radiator, due to the steam given off if the cooling water boils.

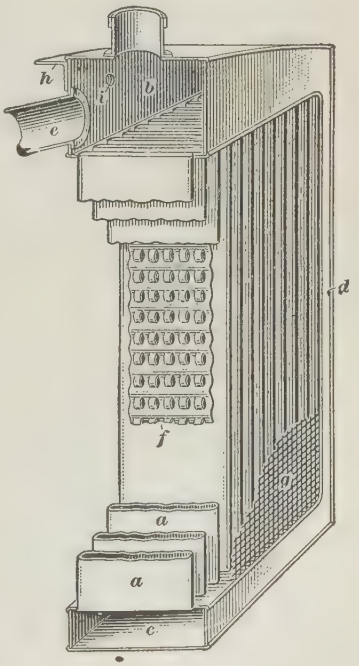

FIG. 10

17. In modern cars employing tubular radiators with flat tubes, the assembly of the two tanks and vertical tubes is placed in a separate shell.

The manner in which the tubes are assembled, and the cooling surfaces extended, in Long radiators is shown in Fig. 11. The tubes *a* are made of thin sheet copper or sheet brass; the extended surfaces *b* are formed of sheet copper or sheet brass

bent either to form rectangular cells, as shown in (*a*), or to give a zigzag effect, as shown in (*b*), and to serve also as spaces for the vertical tubes, to which they are soldered.

18. Cellular-Radiator Construction.—The group of cells around which the water circulates in radiators of the cellular type is formed in various ways. In one construction in wide use, the cells are formed of individual tubes of square or hexagonal cross-section that are laid side by side in such a manner that there is a water space around them. In another widely used construction, sheets of metal are bent to form cells that have water spaces around them when suitably assembled. It is urged in favor of the individual-tube construction that, in

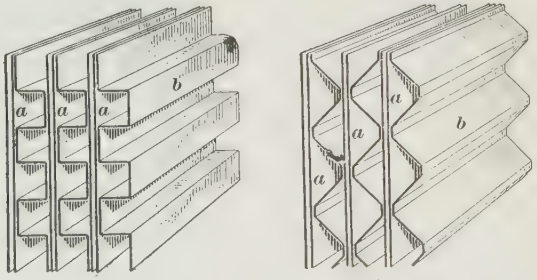

FIG. 11

case of leakage, repairs can be executed with great facility by any one expert in the use of a soldering iron, as a tinsmith, for instance.

The general construction of cellular radiators does not differ from that of tubular radiators; there is a top and bottom tank, to both of which the water spaces formed by the cells are connected, and in modern practice the radiator core is enclosed in a separate radiator shell. The tanks are made of copper, brass, or tin plate; the cells are made of very thin sheet brass or sheet copper. Tin plate is unsuitable for cell material, as the cooling water would quickly rust holes through tin plate of the extreme thinness necessary.

19. In the *Fedders cellular radiator,* individual copper tubes, either $\frac{5}{16}$ or $\frac{3}{8}$ inch square, are employed. These, as

shown in Fig. 12 (*a*), are enlarged at both ends and are assembled either staggered, as shown in (*b*), or in straight lines, the ends being soldered together. A cross-section through a few tubes of a staggered assembly is presented in (*c*); this view clearly shows the tortuous water passages formed by staggering the tubes. When a staggered-tube assembly is used, it is gener-

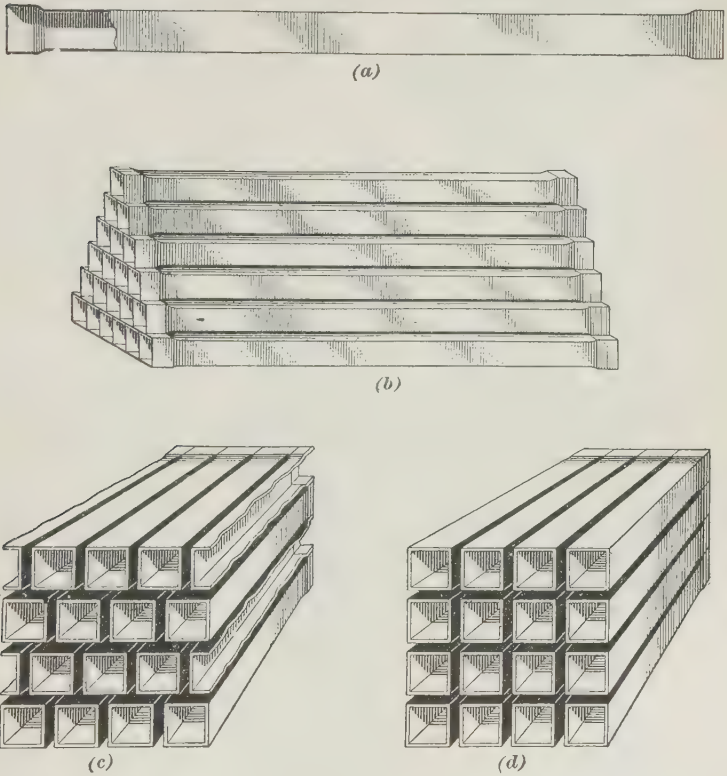

FIG. 12

ally placed so that the straight water passages *a* are horizontal, thus forcing the water to follow a zigzag path in passing downwards through the radiator.

A cross-section through a tube assembly in which the tubes are set in straight lines is shown in (*d*). Here, the water passages are in line both vertically and horizontally, and hence the

water passes downwards through the radiator in straight lines. This arrangement of the tubes permits a freer water circulation, but is not so efficient, so far as cooling the water is concerned, as the staggered-tube assembly.

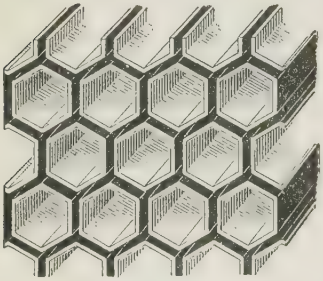

FIG. 13

The water spaces are about $\frac{3}{64}$ inch in width and about $3\frac{1}{2}$ inches deep, the individual tubes being about 4 inches long.

20. When hexagonal tubes are used in the construction of cellular radiators of the individual-tube type, these tubes are enlarged at the ends in the same manner as square tubes; the individual tubes are then nested,

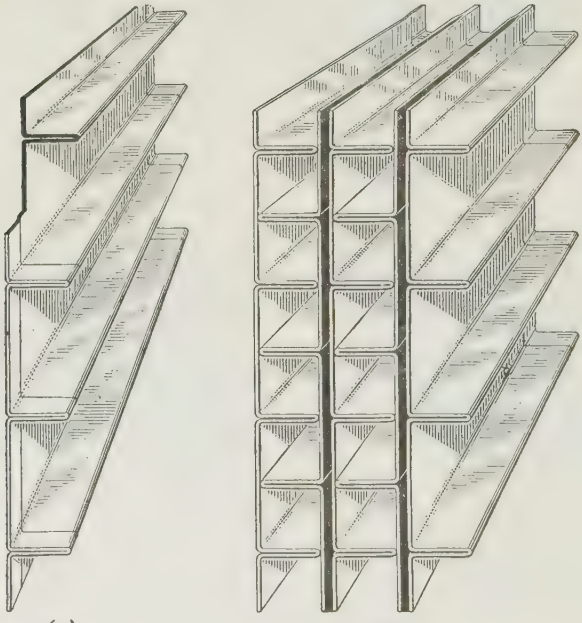

FIG. 14

as is shown in Fig. 13, so that the tubes lie in horizontal rows. When thus nested, the water spaces, shown black in the illustra-

tion, between adjacent tubes in the horizontal rows are vertical, and a better water circulation is insured than is possible if the tubes are nested in parallel vertical rows. As an inspection of Fig. 13 shows, a cross-section of the tubes greatly resembles a honeycomb; this resemblance has led to calling this type *honeycomb radiators*. Strictly, the term honeycomb radiator should be applied only to those constructed with hexagonal individual tubes nested as shown.

21. Cellular radiators in which the cells are formed by bending long strips of sheet copper or sheet brass, frequently

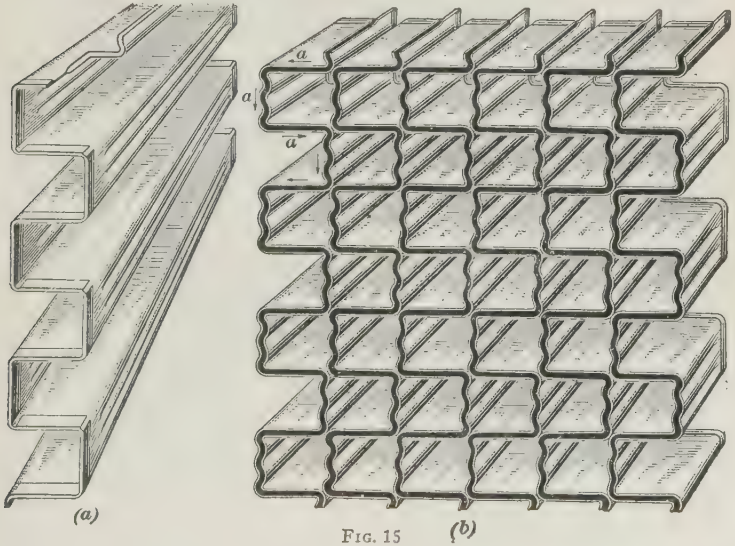

FIG. 15

have their cores made from strips bent as shown in Fig. 14 (*a*). These strips have a width equal to the desired depth of the radiator core, and are assembled as shown in (*b*), thus forming vertical water spaces ranging from $\frac{3}{64}$ to $\frac{1}{16}$ inch in width and having a depth about $\frac{1}{2}$ inch less than the depth of the core. The ends of the water spaces are closed by soldering. The construction shown is employed in the *Mayo* and some other makes of radiators.

Radiators constructed as shown in Fig. 14 naturally do not have so much cooling surface per unit of area as cellular radi-

ators with individual tubes, since there are no horizontal or inclined water spaces joining the vertical water spaces.

22. The cells used in the *Livingston radiator* are bent up from strips of sheet metal in such a manner and are so assembled that they overcome the objection mentioned in Art. **21**; in this radiator, the water spaces surround the four sides of each cell, which is square in cross-section.

The construction of the Livingston radiator cells is illustrated in Fig. 15. In view (*a*) is shown one of the strips from which the core is made; this is bent up from sheet copper having a width of 4 inches, the vertical part of each bend being corrugated to stiffen it, as shown. All horizontal bends are left plain. The bends are alternately wide and narrow, so that when two strips are assembled as shown in the cross-sectional view (*b*) there is formed between them a water space through which the water passes in the direction of the arrows *a*. The pairs of strips are assembled side by side, as shown in (*b*), which view clearly indicates that the four sides of each cell are surrounded by water. The ends of the water spaces are closed by soldering, and the whole assembly is held together by solder.

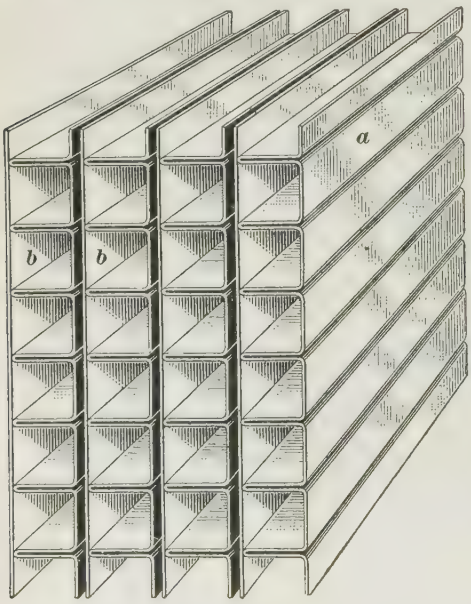

FIG. 16

23. In the *McCord square cellular radiator* the water spaces are formed of bent strips *a*, Fig. 16, and plain vertical strips *b*. Each bent strip is so formed as to have horizontal

water spaces, as shown, and therefore each cell is surrounded by water on its four sides. The cells are square in cross-section. The circulation of water is mainly through the vertical water passages.

24. In *Harrison cellular radiators* the cells are hexagonal, as shown in Fig. 17. In the standard Harrison cellular radiators, shown in (*a*), each vertical tube *a* with its horizontal water spaces is separated from the next vertical tube by a sheet-metal spacer *b*, bent as shown; consequently, only four sides of

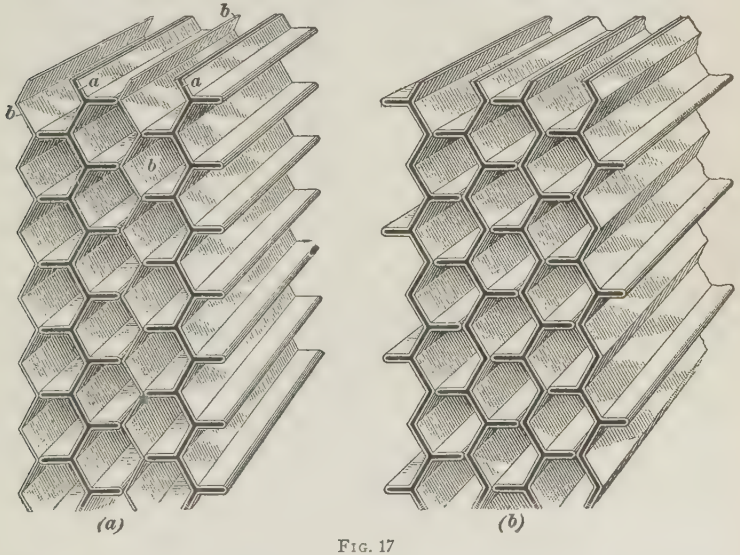

FIG. 17

each cell contain water. In the special Harrison radiators, shown in (*b*), no spacers are used, and the six sides of each cell are surrounded by water; consequently, when radiators of the same size are compared, the special radiator has one-half as much again cooling surface as the standard radiator.

25. Radiator Overflow, Drain, Connections, and Supports.—All modern radiators are fitted with an overflow pipe that carries off surplus water due either to filling the cooling system too full or to expansion of the water, and also any steam formed while the engine is in operation.

26. Provision for draining the radiator of all the contained water is usually made by fitting a drain cock to the bottom of the bottom tank, although in some cases, where part of the cooling system is located at a lower level than the bottom of the lower tank, the drain cock is applied to the lowest point of this part. Generally, the drain cock is located where it will surely drain the entire cooling system.

27. The top and bottom connections of the radiator to the metallic pipes connected to the top and the bottom of the cylinder water-jacket or water-jackets are always made by means of rubber-lined and rubber-covered hose that is fastened on by hose clips of the same form as those used with ordinary garden hose. The hose makes a flexible connection that prevents the transmitting of engine vibration to the radiator; likewise, the hose, being flexible, prevents undue stresses, caused by swaying of the radiator or engine on account of distortion of the chassis frame in running the car over rough roads, from coming on the radiator.

28. Some radiators are supported by lugs incorporated in their construction. These lugs usually rest on the side members of the frame, to which they are bolted. A fairly thick leather pad or a soft-rubber pad is usually inserted between the lugs and the frame to prevent vibrations from being transmitted to the radiator, which action would tend to destroy the soldered joints and thus cause the radiator to leak. Some manufacturers do not bolt the lugs tightly to the frame, but hold them by the pressure of springs placed between the heads or nuts of the holding-down bolts and the lugs or frame, thus forming a connection that can yield slightly if the frame is distorted. In many cases the radiator is set on top of a front cross-member of the frame and is bolted thereto, with a leather or rubber strip placed between the cross-member and the radiator.

In most cars, the top of the radiator is prevented from swaying lengthwise of the car by running a brace rod from the rear of the top tank to the front of the dash.

29. Circulating Pumps.—All pumps used in automobiles for circulating the cooling water are of the rotary type,

as distinguished from the reciprocating, or plunger, type. There are two general classes of rotary pumps; namely, the *centrifugal* and the *positive,* or *fixed-volume-per-revolution, class.* Positive circulating pumps are either of the *gear* or the *sliding-vane type;* such pumps were formerly used to a limited extent on a few makes of cars, but they have been displaced entirely by the centrifugal pump.

The general appearance of the particular type of centrifugal pump used in automobile work is shown in Fig. 18. It consists

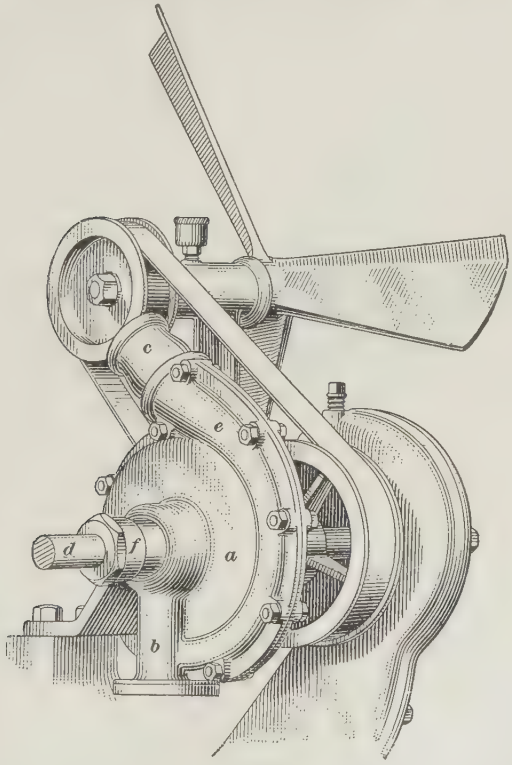

FIG. 18

of a casing *a* made in halves, a water inlet *b* connected to the bottom tank of the radiator, a water outlet *c* connected to the bottom of the cylinder water-jacket, and a disk with backwardly curved vanes inside the casing *a,* the disk being

fastened to the shaft *d* and rotated by it at high speed. Through the passage *b* the water enters at the center of the vanes on the disk mentioned, which is called the *rotor* and also the *impeller*. The water entering the revolving impeller is carried around with it and at the same time travels outwards toward the periphery of the impeller, whence it is discharged at a high velocity into a tapering circular passage *e* around the edge of the casing *a* and passes onward to the discharge outlet and thence to the water-jacket. Where the driving shaft passes through the pump casing, the latter is fitted with a packing nut *f*, and some fibrous packing, like hemp, flax, or cotton wicking, is used to make a water-tight joint.

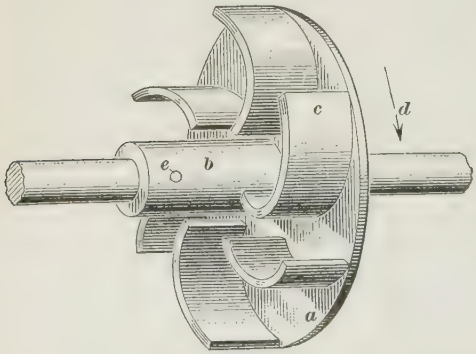

FIG. 19

The casing is usually made of some rust-resisting material like cast iron or bronze, although lead alloys are occasionally used.

30. The rotor, or impeller, of a centrifugal circulating pump is shown in perspective in Fig. 19. It has a large disk *a* cast in one with a central hub *b* and the backwardly curved blades, or vanes, *c*, the direction of rotation being indicated by the arrow *d*. The rotor is usually cast of bronze and is fastened to its shaft either by a small pin *e* driven through the hub and shaft, or by a small setscrew. The water enters around the hub of the rotor and is discharged at its periphery.

31. In most cases the circulating pump is driven by some auxiliary shaft, as in Fig. 18, where the auxiliary shaft *d* also drives the fan. In many cases the pump shaft is an extension of the camshaft, the pump then being located at the forward end of the engine. In a few cases the circulating-pump shaft and the fan shaft are one piece, and the pump is belt driven.

All four-cylinder and six-cylinder engines, and most eight-cylinder and twelve-cylinder engines employing a forced circulation system, have only one circulating pump; the Packard "Twin Six" and Cadillac "Eight" use a separate pump for each cylinder block.

32. A centrifugal pump is not positive in its action; that is, it does not deliver a definite volume of water per revolution under all conditions. Thus, if by any mishap the water outlet is closed, the water in the pump will only be whirled around with the rotor. The pressure will not be much greater under this condition than when the pump is discharging at a moderate rate; it never becomes high enough to injure any properly constructed part. This fact has led to the universal adoption of the centrifugal pump for circulating the cooling water.

A centrifugal pump will continue to give fair service even after the parts are considerably worn. A loose fit between the edges of the vanes and the casing will allow some of the water to flow back toward the center of the pump, however, and the eddy currents thus set up will cause a loss of efficiency.

33. On some of the older Haynes and Apperson cars, many of which are still in use, a so-called sliding-vane pump was employed for circulating the cooling water. A pump of this kind is shown in Fig. 20 (*a*). It is composed of a casing *a*, a rotating piston *b*, and two vanes, or wings, *c* and *c'* with springs *d* between them. The piston *b* is rotated by a shaft *e*, shown dotted, which is usually driven from either the engine camshaft or the magneto shaft; the piston *b* is concentric with the shaft *e*. The piston and the shaft are mounted eccentrically in a circular machined chamber of the pump casing, as shown. The water coming from the radiator flows to the pump through a pipe connected at *f* and leaves through a pipe connected at *g*, which pipe, in turn, communicates with the bottom of the cylinder water-jacket or water-jackets. An inlet port *h* and an outlet port *i* are cut through the wall of the circular chamber of the casing. The two vanes *c* and *c'* are flat and free to slide in a slot machined directly across the

piston; they are shown in perspective at (*e*). The one wing has driven in it two pins that enter corresponding holes in the second wing; when the two wings are assembled in the piston, each pin is surrounded by a spring, shown at *d*, view (*a*). A perspective view of the piston is shown at (*d*), in which view the slot previously mentioned can be clearly seen. A perspective view of the casing is shown at (*b*), and of the cover that closes the casing at (*c*). The lowest part of the casing is fitted with a drain cock.

The action of the pump depends on the motion of the vanes, or wings, in the circular chamber of the casing. Suppose that the piston *b* is in the position shown in view (*a*) and that it

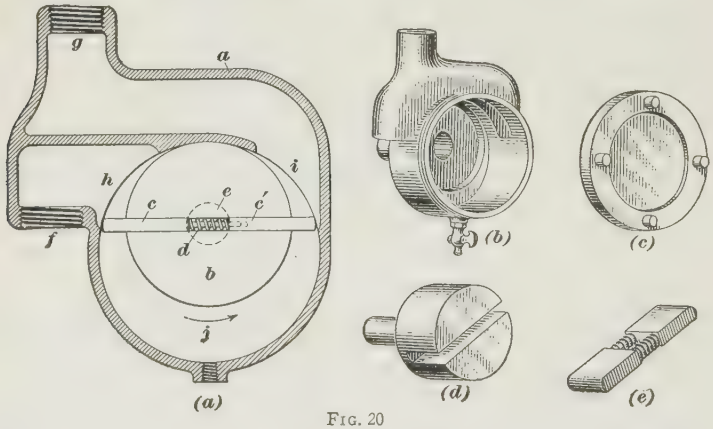

FIG. 20

starts to rotate in the direction of the arrow *j*. As soon as the vane *c* has covered the lower edge of the intake port *h*, it drives the water in the crescent-shaped space between the piston *b* and casing *a* before it and out through the outlet port *i*. In the meantime, as soon as the vane *c* has covered the lower edge of the inlet port *h*, water is drawn through the port into the space behind the vane *c* until it has nearly reached the position of the vane *c′*. As soon as the vane *c′* passes the lower edge of the port *h*, it drives water before it and draws in water behind it; the two blades thus alternate in driving the water before them, thereby producing an almost continuous flow of water.

34. Antifreezing Mixtures for Cooling System. If a car is to be used in very cold weather, it is advisable to fill the cooling system with some liquid that will not readily freeze. In weather not colder than 10° F. above zero, especially if a wind is blowing, it requires only a short time for water to freeze in the radiator if the engine is stopped out of doors. The freezing may be prevented for a considerable time, however, by covering the radiator with a blanket or a robe.

Various substances may be mixed with water in order to lower its freezing point; those most commonly used are wood alcohol, denatured alcohol, calcium chloride, and glycerine.

TABLE I

FREEZING POINT OF MIXTURES OF DENATURED ALCOHOL AND WATER

Percentage of Alcohol	Percentage of Water	Freezing Point of Mixture. Degrees F.	Specific Gravity at 60° F.
10	90	27 above zero	.988
20	80	19 above zero	.978
30	70	10 above zero	.968
40	60	2 below zero	.957
50	50	18 below zero	.943

TABLE II

FREEZING POINT OF MIXTURES OF WOOD ALCOHOL AND WATER

Percentage of Alcohol	Percentage of Water	Freezing Point of Mixture. Degrees F.	Specific Gravity at 60° F.
10	90	23 above zero	.987
20	80	10 above zero	.975
30	70	2 below zero	.963
40	60	20 below zero	.952
50	50	40 below zero	.937

35. Tables I to V, from experiments made by the U. S. Bureau of Standards, give the approximate freezing points of

various mixtures of wood alcohol, denatured alcohol, glycerine, and water. The experiments were made with the ordinary commercial grades of wood alcohol, denatured alcohol, and glycerine.

TABLE III

FREEZING POINT OF MIXTURES OF GLYCERINE AND WATER

Percentage of Glycerine	Percentage of Water	Freezing Point of Mixture Degrees F.
10	90	29 above zero
20	80	21 above zero
30	70	12 above zero
40	60	zero
50	50	15 below zero

TABLE IV

FREEZING POINT OF MIXTURES OF DENATURED ALCOHOL, GLYCERINE, AND WATER

Percentage of Alcohol	Percentage of Glycerine	Percentage of Water	Freezing Point of Mixture. Degrees F.
5	5	90	25 above zero
10	10	80	18 above zero
15	15	70	9 above zero
20	20	60	8 below zero
25	25	50	26 below zero

TABLE V

FREEZING POINT OF MIXTURES OF WOOD ALCOHOL, GLYCERINE, AND WATER

Percentage of Alcohol	Percentage of Glycerine	Percentage of Water	Freezing Point of Mixture. Degrees F.
5	5	90	25 above zero
10	10	80	16 above zero
15	15	70	5 above zero
20	20	60	11 below zero
25	25	50	31 below zero

When using an alcohol as well as an alcohol and glycerine antifreezing mixture, it must be remembered that alcohol vaporizes and passes out of the cooling system more rapidly than does water. It is therefore necessary in order to maintain the proper proportions to add more alcohol than fresh water. The vapor of the alcohol is inflammable. Care should therefore be taken not to bring a naked light near the filler opening of the radiator when the filler cap has been removed. None of the alcohol solutions will injure rubber or attack the different metals in the cooling system.

Glycerine and water, as consultation of Table III shows, form mixtures that stay liquid at lower temperatures than water alone. There are two objections to glycerine, however, which are its high price and the fact that it is liable to attack the rubber of the hose connections to the radiator. When glycerine is used in combination with wood alcohol or denatured alcohol the glycerine retards the vaporization of the alcohol, and for this reason the glycerine, water, and alcohol mixtures are recommended by some automobile manufacturers.

36. There are a number of prepared antifreezing materials on the market, sold under various trade names, some of which are in liquid form and some in the form of powder, ready for dissolving in water. If any of these materials are employed, the maker's directions should be implicitly followed, especially if there are any aluminum water manifolds or aluminum water passages employed, as many of the materials have a highly corrosive action on aluminum castings.

37. Kerosene, also called coal oil, is sometimes used as a cooling agent, as it has a very much lower freezing point and a higher boiling point than water. Kerosene has a very marked solvent action on the rubber hose connections, it has the property of penetrating the slightest cracks in the soldered joints of the radiator core, its vapor is highly inflammable, and it gives off a disagreeable smell when heated. For these reasons the use of kerosene is not generally recommended, although in isolated cases it has been used successfully.

38. Calcium chloride, where readily obtainable, is sometimes mixed with the cooling water to form an antifreezing mixture. Only chemically pure calcium chloride should be used, however. The impurities in ordinary commercial calcium chloride are apt to attack some of the metals or alloys of the cooling system, especially aluminum, zinc, and solder. Table VI gives the approximate freezing points of various proportions of calcium chloride and water.

Before using a calcium-chloride solution it is advisable to make a test for acidity. This may be done by placing a strip of blue litmus paper, which can be bought at any drug store, into a

TABLE VI

FREEZING POINT OF MIXTURES OF CALCIUM CHLORIDE AND WATER

Calcium Chloride per Gallon, of 231 Cubic Inches, of Water Pounds	Freezing Point Degrees F.
1.0	27.0 above zero
2.0	18.0 above zero
3.0	1.5 above zero
3.5	8.0 below zero
4.0	17.0 below zero
5.0	30.0 below zero

sample of the solution. If this litmus paper turns red, the solution is acid and must not be used without first neutralizing it. Neutralizing is done by adding slaked lime, a little at a time, until a strip of blue litmus paper remains blue. Calcium-chloride solutions are used very little at present.

39. The greatest point in favor of calcium chloride as well as the other prepared antifreezing materials mentioned in Art. **36,** is the fact that the material lowering the freezing point does not evaporate, and hence only addition of water is necessary to make up for that evaporated. With any of the alcohol or alcohol and glycerine solutions, however, alcohol

must also be added periodically, as the alcohol evaporates even quicker than the water. To offset the advantage of calcium-chloride solutions, and prepared antifreezing materials of which calcium chloride is usually the chief constituent, there is the danger of occasional destruction of a radiator by the eating away of the solder, and of other parts of the cooling system consisting of an aluminum alloy, or zinc alloys.

40. The freezing point of mixtures of denatured alcohol or wood alcohol and water can be measured by finding the specific gravity of the mixture and consulting either Table I or Table II. By specific gravity of a mixture is meant the ratio of the weight of a given volume of the mixture to the weight of an equal volume of water. In practice, the specific gravity of an antifreezing mixture is measured by use of a hydrometer graduated to give specific gravity readings for liquids lighter than water. Such a hydrometer is placed into a quantity of the mixture and the specific gravity is read on the scale of the hydrometer stem at the point where the stem emerges from the liquid. The mixture to be tested should have a temperature of not less than 55° F. nor more than 65° F.

Hydrometers for liquids lighter than water can be obtained from most automobile-accessory supply houses or dealers in scientific instruments.

No specific gravity figures for mixtures other than those given in Tables I and II are available.

WATER-COOLING AUXILIARIES

41. Thermostatic Water-Temperature Control. Practical experience has shown that in a water-cooled engine best results in point of fuel economy and power developed are obtained when the temperature of the cooling water is approximately 30° F. below the boiling temperature of water, or in the neighborhood of 180° at or near sea level. When the cooling system falls much below this temperature, there is a marked condensation of the heavier parts of the fuel, that is, a return to the liquid state; this liquid does not ignite but passes uncon-

sumed past the pistons into the crankcase, diluting the oil and thereby impairing its lubricating value, to the detriment of the engine. Furthermore, the gasoline consumption is unnecessarily high, as a richer mixture is required than would otherwise be the case, in order to have the engine deliver the same power. On the other hand, if the cooling-water temperature is much higher than 30° F. below the boiling point, the incom-

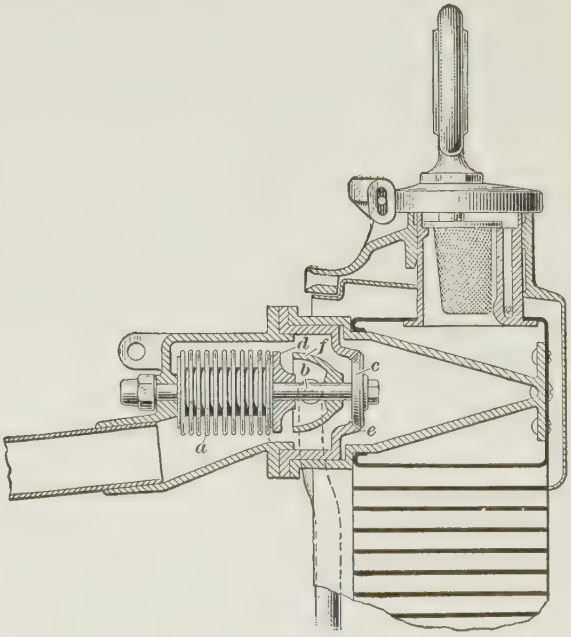

FIG. 21

ing fresh charge is expanded more than advisable, and consequently the weight of the charge taken in is lessened, resulting in lowering the power output of the engine. This discussion tends to show the desirability of bringing the cooling water very rapidly to the most economical temperature, and of constantly maintaining this temperature, preferably by automatic means.

Automatic temperature control of the cooling water is usually accomplished in one of two ways. In the most widely used method the circulation of the cooling water through the radi-

ator and water-jacket of the cylinders is varied; in the second method the quantity of air passing through the radiator is changed.

42. The construction of a *Sylphon* thermostat, as applied to many Packard Twin-Six cars, is shown in Fig. 21; the thermostat, as clearly shown in Fig. 2 at *j*, is mounted at the rear on the top tank of the radiator. The controlling element *a*, Fig. 21, is of thin copper corrugated like a bellows and carries on a stem *b* two valves *c* and *d*; the valve *c* controls the inlet passage to the radiator, and the valve *d* controls the inlet to the by-pass pipe, shown at *i* in Fig. 2. The element *a* in Fig. 21 is partly filled with ether; when heated this liquid vaporizes and exerts a pressure which elongates the element to an extent depending on the temperature of the water surrounding it. The inlet valve *c*, when the engine is cold, is seated on the seat *e* of the thermostat housing; the by-pass valve *d*, when the engine is cold, is away from its seat *f*. The by-pass pipe *i*, Fig. 2, connects to the annular cavity of the seat *f*, Fig. 21. While the engine is cold, the by-pass is wide open and the radiator inlet is closed; therefore, the water circulates only around the water-jackets of the cylinder blocks. As the cooling water heats, the element *a* elongates, thereby partly shutting off the by-pass and opening the radiator inlet, so that there is a circulation partly through the by-pass and partly through the radiator. Finally, when the water has reached the temperature the thermostat was built for, the by-pass is closed entirely and the radiator inlet is wide open, and then all the cooling water circulates through the radiator. When the water cools, the element *a* contracts, thereby opening the by-pass again

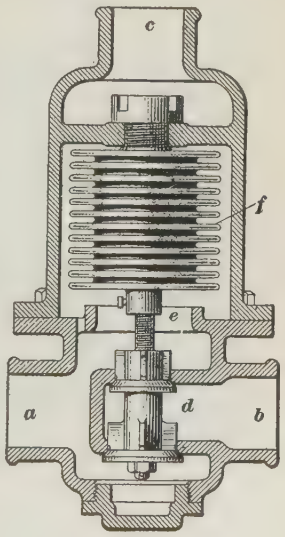

FIG. 22

43. The Sylphon thermostatic regulator is built in the form shown in cross-section in Fig. 22 for attachment to cars not already fitted with temperature control. It is placed in the lower hose connection between the pump and radiator, with the spigot *a* toward the pump and the spigot *b* toward the radiator. The spigot *c* is connected by a hose to a T fitting in the hose connection from the top of the water-jackets to the top tank of the radiator; this forms the by-pass.

The double-seated, and hence balanced, valve *d* controls the inlet to the radiator; the valve seat *e* in connection with the bottom of the thermostatic element *f* controls the by-pass.

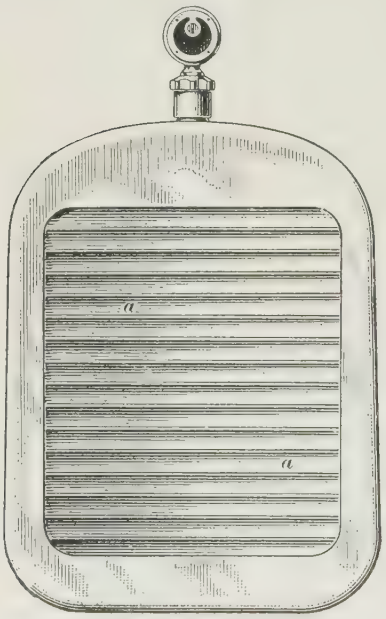

FIG. 23

44. In many Columbia cars a Sylphon thermostat, instead of controlling the water, controls automatically the quantity of air passing through the radiator by operating a shutter fitted to the front of the radiator, the shutter having a number of horizontal leaves *a*, Fig. 23, pivoted at their ends, the construction being similar to that applied to the window shutters of many dwelling houses.

The installation of the thermostat is shown in Fig. 24. A fitting *a* in the form of a cross is placed into the upper radiator connection; a metallic cup closed at the bottom is screwed into the top of the fitting *a*. This cup is partly filled with ether and is surrounded by the cooling water; the top of the cup is connected by the pipe *b* to the element *c*, which lengthens as the pressure of the ether vapor increases, and through the medium of the lever *d*, suspended at one end by the link *e*, and the

rod *f* opens the leaves of the shutter to an extent depending on the temperature of the cooling water. The air supply to the radiator is thus automatically controlled.

45. Some of the Hudson Super-Six cars are equipped with a Sylphon thermostat placed just as shown in Fig. 21, and

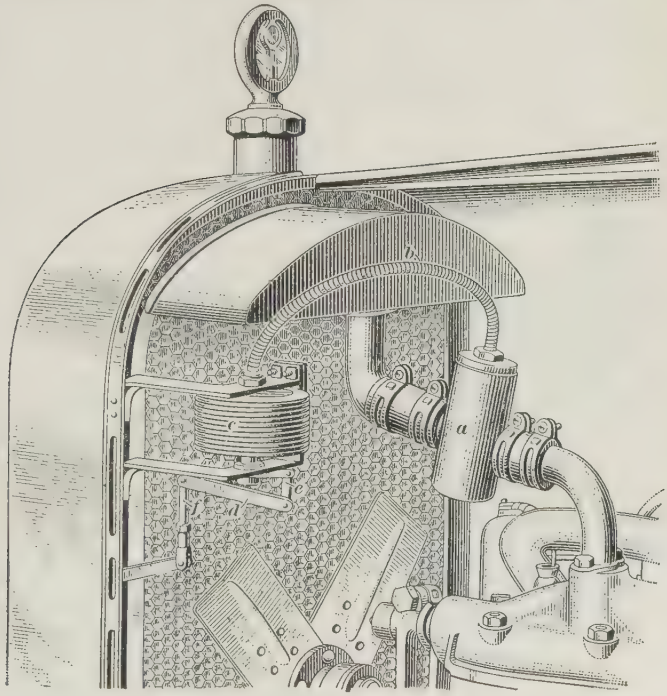

FIG. 24

have also a hand-operated radiator shutter like the one shown in Fig. 23.

A radiator thermometer, to show the temperature of the cooling water, while not indispensable, is a desirable adjunct to thermostatic or hand control of the cooling-water temperature.

46. Hand Water-Temperature Control. — While thermostatic control of the cooling-water temperature is desirable, the fact is that comparatively few cars are equipped with it. Therefore, on cars without thermostatic control various

expedients are resorted to in cold weather by their drivers to cause the engine to heat up quickly and stay hot for some time when the car is not in use. A common method is to disconnect the fan in cold weather; this does aid in heating the engine quickly, but must be supplemented by a hood and radiator cover, or by a blanket or quilt placed over the hood and radiator to keep the engine warm while the car is temporarily not in use. Frequently a piece of sheet metal or cardboard is placed over part of the radiator in order to reduce its cooling surface, or some radiator cover made of fabric is attached to the radiator, the cover having an opening that can be changed in area by a roller curtain. Such radiator covers and hood covers for winter use and to fit almost every make of car are regularly manufactured and can be obtained through nearly every garage or automobile-accessory supply store.

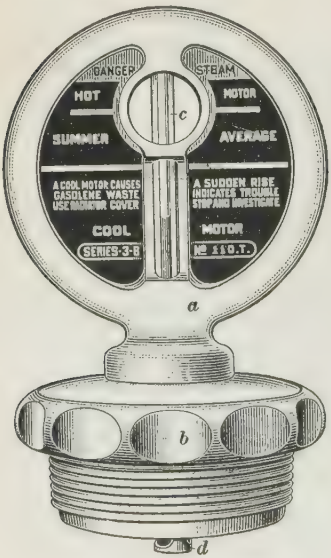

FIG. 25

47. Radiator Thermometers.—Irrespective of whether an engine is fitted with any system of cooling-water temperature control or none at all, it is desirable to have an instrument in plain view of the driver that will show the temperature of the cooling water, as the driver is thereby informed if the engine is operating under the best conditions, and it enables him to apply proper remedies if this is not the case. Obviously some form of thermometer will serve as an indicating instrument; the one most widely used is known as the Boyce Motometer, is applied to the radiator cap, and is shown in Fig. 25. It consists of a cast-metal frame *a* held centrally to the radiator cap *b* by a nut, a water-tight joint being made by soft-rubber washers on both sides of the cap. Inserted in the

middle of the frame is a thermometer *c* using a red liquid; the bulb of the instrument is protected against injury by a metal tube *d*.

The first Boyce motometers made were marked on the frame to read to degrees Fahrenheit, just like any ordinary thermometer; as comparatively few drivers could correctly interpret the temperature readings, the instrument is now marked on its face with the inscriptions plainly shown in the illustration. The motometer is installed in such a position in the radiator cap that when the cap has been screwed home the instrument faces the driver's seat.

AIR COOLING

48. In order that a cylinder may be cooled sufficiently with air to keep the temperature down to a working limit, it is necessary to provide a greater radiating surface with which the air can come in contact than is presented to the atmosphere by a cylinder having a smooth exterior. The increased radiating surface is secured by placing projections on the parts of the cylinder that need the most cooling. These projections are usually in the form of fins, and may be either thin, flat rings at right angles to the cylinder, or thin, flat strips placed radially and running lengthwise of the cylinder. In either case, the inner edge of the fins forms an integral or a substantially integral part of the cylinder casting. Other methods of forming an increased radiating surface, such as using radial pins either cast integral with the cylinder or substantially attached thereto, were formerly employed, but they have become obsolete.

Under normal conditions of operation, the air-cooled engine runs much hotter than one cooled by water or some other liquid.

49. There are three methods of bringing air into contact with the radiating surfaces of the cylinders. In the first method, the passage of the car through the air is relied on; in the second method, air is blown against the radiating surfaces by a rotating fan; and in the third method, the parts with which the air is to be brought into contact are enclosed in a

casing and a current of air is either forced through or drawn through the casing by means of a fan. A greater amount of air can be brought into contact with the radiating surfaces in this manner than when they are not enclosed by a casing.

The air-cooling method first mentioned is obsolete. The second method has been used in the Cameron car, in some models of the Franklin cars, and in a number of other now obsolete cars. The method in which air is forced by a fan or a blower through a casing surrounding the cylinders has been used on the Frayer-Miller cars, no longer made.

50. In the Franklin air-cooled automobiles, there is employed the variation of the third method mentioned in Art. **49**

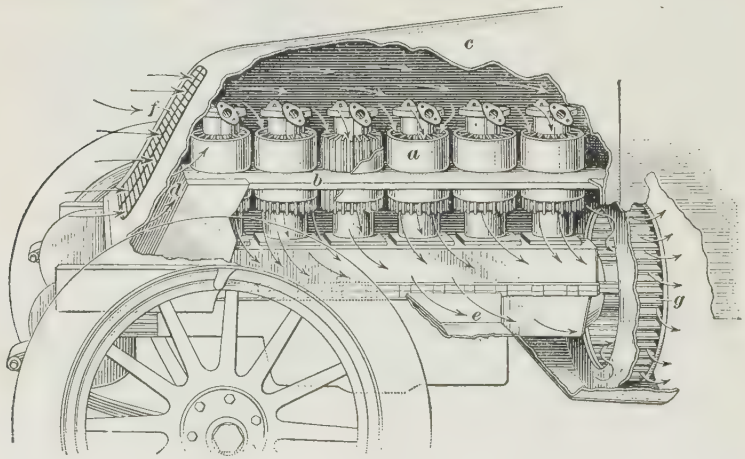

FIG. 26

in which air is drawn through a casing surrounding the cylinders. This system, as carried out in the Franklin six-cylinder cars, is illustrated in Fig. 26, where some of the parts of the car have been cut away and some engine details that would interfere with a clear showing of the cooling system have been omitted.

Each cylinder of the engine has vertical thin metal fins, or flanges, that are cast in the cylinder walls; also, each engine cylinder is surrounded by a short cylindrical sheet-metal air jacket *a* that is open at the top and the bottom. These air

jackets are set through a horizontal metal deck *b* that touches the front of the dashboard and is touched by a ledge on the sides of the hood *c*. An inclined sheet-metal shield *d* reaches from the front of the horizontal deck *b* downwards to the front end of the crankcase; aluminum guards *e* run from the sides of the crankcase to the frame of the car, thus forming a lower compartment which is open at the rear. The upper compartment is open to the air through a large grilled opening *f* in the front of the hood. The flywheel *g* of the engine is a suction fan and draws air through the opening *f* into the upper air compartment, and thence, as indicated by the arrows, down through the air jackets of the cylinders into the lower compartment, the warm air being discharged to the rear of the flywheel. The air in passing over the cooling flanges and outer surface of the cylinders cools these by absorbing heat and carrying it away.

FANS

51. A fan forms an essential part of any cooling system, its purpose being to draw air through the radiator in case of water cooling, and over the cylinders in case of air cooling.

Fans for water-cooled engines are either built up from sheet-metal blades riveted to a cast-metal hub, as shown in Figs. 1, 3, and 24, or they are cast in one piece from aluminum, as shown in Figs. 2 and 18. The number of blades in the fan ranges in usual practice from two to six. As a general rule the fan has only one row of blades, but a few cars employ a fan with two rows of blades separated a little distance.

In most cars the fan is driven either by a flat leather or fabric belt, as shown in Figs. 1, 3, and 18, or by a so-called **V** belt, which has a roughly triangular cross-section with the apex of the triangle cut off, and runs in **V**-shaped grooves of the driving and driven pulleys; such a belt is used for the fan shown in Fig. 2.

52. As fan belts stretch in use, some means of adjusting their tension is always provided. When the general engine construction permits varying the center-to-center distance

between the driving and driven pulleys, it is common practice to mount the fan on an arm pivoted to a stationary stud to which it can be clamped. By first loosening the clamping screw the arm can be swung up to tighten the belt; the arm is then clamped to its stud again.

In some cases the fan is mounted eccentrically on a large cylindrical shaft which can be rotated in a bearing to change the center-to-center distance between the pulleys, and is clamped after the belt is adjusted.

In a few cases the fan is carried by a bracket which can be moved bodily some distance, the screws fastening the bracket being placed through slots therein.

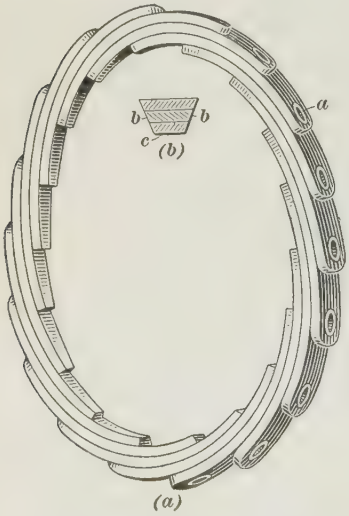

FIG. 27

53. A **V**-type fan belt known as the Flexo is shown in perspective in Fig. 27 (*a*). It is built up from tapering pieces of leather, all alike and assembled by rivets *a* with washers beneath the rivet heads. The pieces of leather are so shaped that when assembled so that four pieces overlap at the rivets the cross-section between rivets is as shown in (*b*). The sides *b*, *b* are in contact with the **V**-shaped groove of the pulleys; the bottom side *c* of the belt does not touch the pulleys.

V belts are also made by putting either two or three strips of leather, at least one of which is continuous, on top of one another, and either cementing, sewing, or riveting them together, after which they are cut to have the cross-section shown in Fig. 27 (*b*). Such belts are rather stiff and therefore do not run well over pulleys of small diameter.

54. With **V**-type fan belts the same means of adjusting the belt tension are employed as with flat belts, but owing to the

shape of the belt another adjustment means is possible, which is to make one of the pulleys in such a manner that its diameter can be increased within certain limits. The principle underlying this is shown in Fig. 28, which does not show the actual construction of such a pulley, however. The pulley is made in two halves *a, b,* the half *a* being fastened to the driving shaft *c*. The half *b* is movable lengthwise in relation to the half *a* and can be clamped rigidly to the half *a*. By bringing the two halves of the pulley closer together, as is seen if view (*a*) is compared with view (*b*), the belt *d* is moved outwards, so that it travels in a circle larger than before.

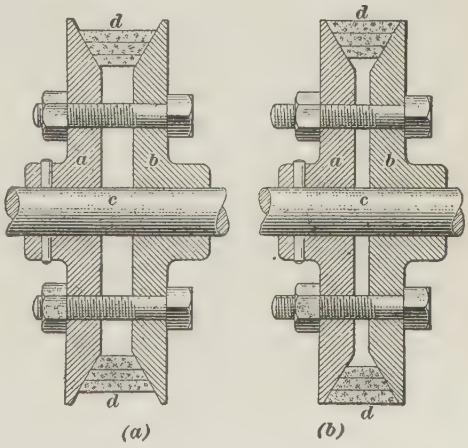

FIG. 28

In the adjustable pulley as actually made, the two halves are pressed from sheet steel, with inclined surfaces where the two halves clamp together. To make the pulley larger, the clamp bolts are loosened and the loose half of the pulley is turned to the left until the belt has the desired tension; the three clamping bolts are then tightened again. The effect of turning the loose half of the pulley to the left is to bring the two sides of the **V** groove closer.

55. A fan is occasionally driven by gears or sprockets and chain from some rotating member of the engine. In that case, if the fan is rigidly connected there would be severe stresses set up in the fan and driving mechanism under sudden speed changes of the engine. To prevent this, it is customary to drive the fan through a friction clutch arranged so it can slip, thereby permitting the fan to slow down, or to increase its speed gradually.

EXHAUST MUFFLERS

PURPOSE OF MUFFLING

56. Gases exhausting unrestricted from the cylinder of an internal-combustion engine pass into the atmosphere at a high velocity, so high, especially at high engine speeds, that the result is a continuous noise that can be likened to a series of sharp detonations. This noisy exhausting of the gases is decidedly objectionable, and for this reason devices are used on every car that will muffle the detonations to a degree that will render them unobjectionable. Any device used for this purpose is called an **exhaust muffler.**

Generally, the exhaust is muffled by leading the exhaust gases into a chamber, or chambers, where they can expand to a low pressure and cool at the same time. In most mufflers, the single large stream of exhaust gases coming from each cylinder is broken up into numerous small streams, or thin sheets, to insure rapid cooling and reduction in velocity. In some mufflers, the cooled exhaust gases are discharged into the atmosphere in a series of fine streams, and in others, especially the most modern mufflers, the discharge is in a single stream. It was formerly common practice either to place a valve of some suitable form between the muffler and the engine, or to incorporate a valve directly with the muffler, the valve being operated by a conveniently located foot-pedal. This valve, known as the **muffler cut-out,** opens directly to the atmosphere, and, when open, it allows the engine to exhaust directly into the air, for testing the regularity of the explosions.

However, the abuse of the muffler cut-out by thoughtless drivers has caused many municipalities to forbid its use, under heavy penalities, while the car is operated upon the highways. This action has been indorsed by the National Automobile Chamber of Commerce, of which many automobile manufacturers are members; consequently, comparatively few modern cars are equipped with muffler cut-outs when leaving the factory.

A good muffler, while effectively muffling the sound of the escaping exhaust gases, will create so little back pressure that the increase in the power of the engine by using a muffler cut-out is so small that it can only be measured in a testing laboratory. This fact is contrary to the common opinion that a large increase in power, especially for hill climbing, is secured by the use of the muffler cut-out.

CONSTRUCTION OF MUFFLERS

57. Fig. 29 illustrates in section a typical modern exhaust muffler of the type that breaks up the exhaust gases into a comparatively few fine streams. It has two cast-iron heads *a* and *b*, and four concentric cylindrical shells *c*, *d*, *e*, and *f* that are held in position by grooves in the two heads. The assembly is held together by long bolts that pass through both heads. The exhaust pipe *g* is attached to the head *a* and discharges into

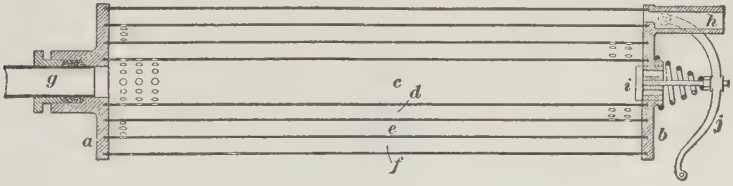

FIG. 29

the inside of the shell *c*. The gases pass through small perforations at the left end of the shell *c* into the larger shell *d*, expanding in doing so, because the volume of the shell *d* is much larger than that of the shell *c*. The gases in the shell *d* pass through perforations at the right end of this shell and expand into the shell *e*; then they pass through holes in the left end of the shell *e* into the outer shell *f*, expanding therein, and, finally, they escape into the atmosphere through the nozzle *h*. The muffler here illustrated has a cut-out valve *i* fitted into the head *b*. When this valve is opened by pulling on a cable attached to the cut-out lever *j*, the exhaust gases can pass from the exhaust pipe *g* through the inside shell *c* and the openings in the valve seat of *i* into the atmosphere.

58. Fig. 30 illustrates, in longitudinal section and in cross-section, a muffler of the type that breaks the exhaust gases into numerous small streams. In this form of muffler there are six cylindrical steel shells, two of which are placed eccentric to the center of the muffler. The exhaust gases enter the central chamber *a* of the muffler, and pass through perforations at the top to the first expansion chamber formed by the annular space between the first and second shells. The gases pass through perforations in the bottom of the second shell into the second expansion chamber, and leave this through perforations

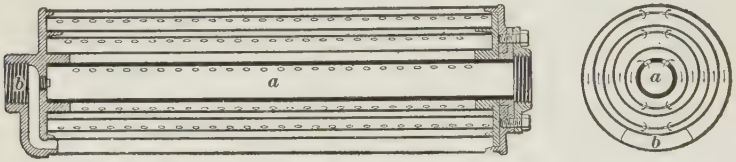

Fig. 30

in the top of the third shell, entering the third expansion chamber, and so on. The gases finally leave the muffler through the exhaust port *b* and pass into the atmosphere.

59. Mufflers are liable to fill gradually with soot (loose carbon). For this reason, they should be taken apart occasionally and cleaned. When a muffler is apart, the shells or cones, especially those which first receive the exhaust gases, should be examined for corrosion. If a cut-out valve is incorporated in the muffler, it also should be cleaned and examined, and, if necessary, repairs should be made.

MUFFLER CUT-OUTS

60. Although many cars are fitted with a muffler cut-out, there are some that are not provided with this device. To meet the demand of owners who desire to place a muffler cut-out on the exhaust pipe, numerous cut-out devices have been placed on the market. Some of them can be applied with very little labor.

61. Fig. 31 illustrates a form of muffler cut-out that will open automatically if an explosion occurs in the muffler, thus acting as a safety valve. It consists of a T-shaped body *a* that is threaded internally at *b* and *c* to fit threads cut on the exhaust pipe. At *d* is formed a valve seat that is normally closed by the valve *e*, which is held to its seat by a spring *f*. A light wire cable is attached to the lever *g*. When this cable is pulled in the direction shown by the arrow, the valve *e* is pushed away from its seat *d* and a direct passage to the atmosphere is provided for the exhaust gases. If at any time the pressure in the

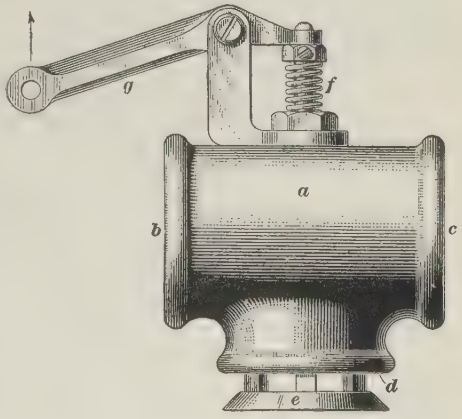

FIG. 31

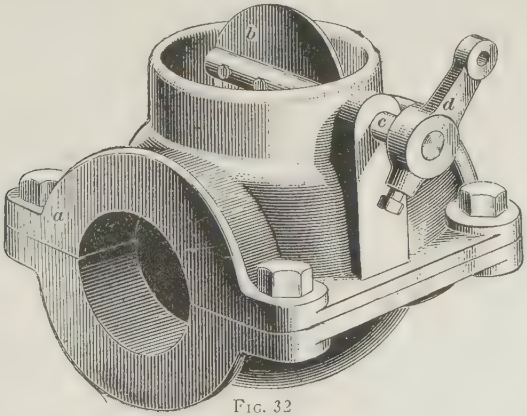

FIG. 32

exhaust pipe is great enough to overcome the tension of the spring *f*, the valve *e* will automatically open outwards.

62. The form of muffler cut-out illustrated in Fig. 32 is intended to be clamped to the exhaust pipe after cutting a

V-shaped notch into this pipe. For this purpose the body *a* is made in halves. The cut-out valve *b*, which is a butterfly valve, is fastened to a shaft *c*. This shaft also carries a crank *d* that serves to turn the valve *b*, which is shown in its open position.

GOVERNING DEVICES

GOVERNING BY HAND OR FOOT

63. All automobile engines and most motor-truck engines are controlled by manipulation of the throttle valve and the position of the spark. More accurately, the control proper is accomplished by regulation of the throttle, and the spark advance is regulated to keep the ignition at its most advantageous point for developing the maximum power of the charges received.

The manipulation of the spark alone is sometimes, but wrongfully, employed to modify the speed of the engine, because, with the spark retarded to cause ignition to occur later than it should, the power of the engine is very materially reduced. This is a most objectionable practice for several reasons: In the first place, it evidently wastes gasoline, because the same result as regards power may be obtained with smaller charges and an earlier spark. Second, the inflammation is so prolonged that it probably is not completed at the time the exhaust valves open, so that the valve seats are exposed to streams of gas still burning. This not only overheats the valves and is liable to warp them, but it soon burns and cuts their ground faces and their seats. Third, the engine is overheated, and preignition of the incoming charge may result, producing explosions in the carbureter and intake pipe. It is, however, permissible to retard the spark to prevent racing, that is, running too fast, when the throttle is nearly closed and the engine is idling, with the car standing still.

64. Inasmuch as automobile and truck engines are operated under wide variations of speed and load, it follows that for correct action the throttle and the spark cannot always be

operated together. For example, a rarefied charge, such as is obtained with the engine running at medium speed, with the throttle nearly closed, will burn in a comparatively slow manner and requires an advanced spark for its prompt combustion. Suppose, now, that the car is running at moderate speed under these conditions, as it may when descending a slight grade, or even on level ground. If a slight up-grade is encountered, the operator will open the throttle to increase the power. Under such conditions the speed of the engine will probably not increase, but it will be found that the spark advance suitable for the previous conditions is too early for the increased charges. This will be indicated by the laboring sound and possible pounding of the engine, either of which sounds may be stopped at once by slightly retarding the spark. Many of the modern ignition systems are fitted with automatic spark control, which takes care automatically of necessary spark variation for all ordinary conditions. This is generally supplemented by hand spark control to meet extraordinary conditions.

65. The manipulation of the throttle valve is effected either by means of a hand throttle lever carried as a general rule at or near the top of the steering-gear column or by a foot throttle lever mounted on the foot-board. Where cars are fitted with hand throttle lever and foot throttle lever, they are usually so connected that either can operate upon the throttle valve. The foot throttle lever, which is commonly called the *accelerator,* is connected to a spring in such a manner as to tend always to close the throttle valve when not pressed by the foot. The hand throttle lever will stay in any position in which it may be placed on its quadrant; the accelerator, however, must be held with the foot if it is used in driving the car, because the spring always tends to return it, thereby closing the throttle. In some cars the accelerator, instead of being depressed to open the throttle, is moved sidewise or forward with the foot. Experienced drivers greatly prefer the use of the accelerator to that of the hand throttle.

66. The principle involved in connecting the hand and the foot throttle levers so that either can operate the throttle valve

is illustrated in Fig. 33. There are two crank-arms *a* and *b* that are independent of each other; both are mounted, and free to turn, on the same stud *c*, which is rigidly fixed in position. The lever *b* has a boss *b'* raised so as to form a stop against which the lever *a* may rest. The rod *d* is hinged to the lever *a* and connects with the hand throttle lever; the rod *e* is connected to the accelerator, and the rod *f* to the carbureter throttle valve. The rods *e* and *f* are hinged to the lever *b*. A helical spring *g* is hooked to the lever *b* at one end and to some stationary part of the car at the other end. This spring *g* is always so mounted that it tends to pull the rod *f* in the right direction to close the throttle valve.

Suppose that the hand throttle lever is operated so as to push the rod *d* in the direction of the arrow *h*. This move-

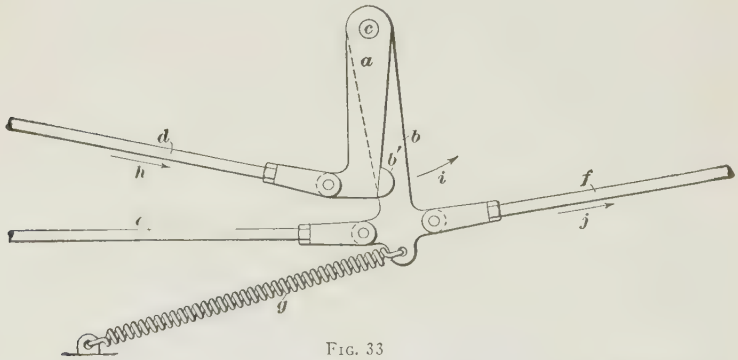

FIG. 33

ment causes the lever *a* to swing in the direction of the arrow *i*, carrying the lever *b* with it in the same direction and causing the rod *f* to move in the direction of the arrow *j*, thereby opening the throttle valve. When the hand throttle lever is operated in an opposite direction, the rod *d* and lever *a* are positively pulled back by that lever; the lever *b* and the rod *f* are pulled back by the spring *g*, however, which tends to keep the projection *b'* of the lever *b* in contact with the lever *a*. It is then evident that if the hand throttle lever is moved, the levers *a* and *b* and the rods connected to them move also, and since the rod *e* connects to the accelerator, this moves in unison with the hand throttle lever.

Now assume that the hand throttle lever has been set so as partly to close the throttle valve and that the accelerator is used, being moved so that the rods *e* and *f* are pushed in the direction of the arrow *j*. The rod *d* and the lever *a* remain stationary, but the lever *b* swings away from the lever *a*; the throttle valve is thus opened, the hand throttle lever remaining at rest. When the pressure on the accelerator is relieved, the spring *g* immediately pulls the lever *b* and the rods *e* and *f* back, thereby closing the throttle valve.

The details of the mechanism explained by the aid of Fig. 33 naturally vary somewhat in different cars.

AUTOMATIC SPEED GOVERNORS

67. A governing device that automatically controls either the maximum speed of the engine or the maximum speed at which a self-propelled vehicle can be driven is known as an *automatic speed governor*. If applied to an engine, it prevents the engine from exceeding the speed the governor is set for and thus prevents injurious racing of the engine when the load is suddenly removed, as, for instance, when the clutch is released without simultaneously closing the throttle, or when there is only a light load on the engine, as occurs when the vehicle is running in low gear or reverse. If the governor is made to function only by the speed of the vehicle, it prevents the vehicle from attaining a speed injurious to itself, by limiting the engine speed on high gear, but this still permits injurious racing of the engine on the lower gears. Therefore, a type of automatic speed governor has been devised that controls both the engine speed and the vehicle speed, the vehicle speed controlling the governor and hence engine speed on high gear, and the engine speed controlling the governor and hence the maximum engine speed on the lower gears; such a device is called an *automatic duplex governor*.

Automatic governors have been applied to a few of the high-priced passenger cars in the past, but none are thus fitted at present. It is different with motor trucks, however, where the majority have governors as standard equipment.

68. There are only two classes of automatic speed governors in actual use at present, namely, *gas-velocity governors* and *centrifugal governors,* both of which control the quantity of combustible mixture admitted to the engine cylinders.

In gas-velocity governors the area of opening of the intake manifold is automatically varied by the difference in the push exerted by the incoming fresh charge, under engine-speed changes, against a spring-loaded valve placed between the throttle and the intake manifold. Governors of this class limit the engine speed on all gears to the maximum speed they are

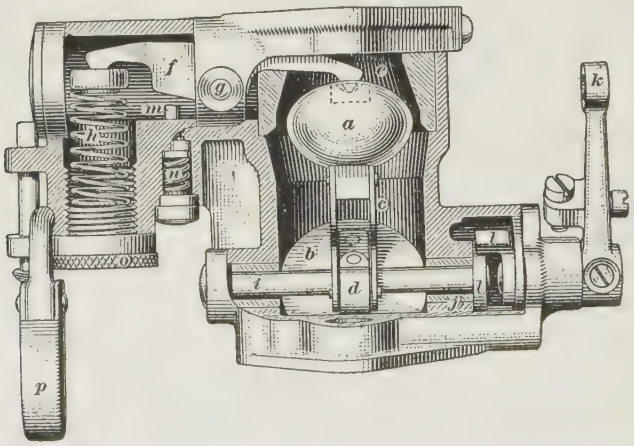

FIG. 34

set for; in other words, the maximum speed of the engine is the same no matter in what gear the vehicle is driven.

In centrifugal governors, centrifugal force acting upon revolving weights changes their positions, an increase of engine speed producing a greater centrifugal force and thus overcoming the resistance of a spring or springs. This change of the governor-weight positions in turn partly closes the throttle valve, thereby preventing any further marked increase of the engine speed. If a centrifugal governor is driven only by the engine, the maximum engine speed is the same on all gears on which the vehicle is driven; if the governor is driven only by

the vehicle, the maximum engine speed is controlled only in high gear, as previously stated.

69. A gas-velocity type of governor known as the *Monarch*, made by the Monarch Governor Company, Detroit, Michigan, is shown in section in Fig. 34. It consists of a hollow, metal member *a*, known as a conoid, which is connected to a butterfly valve *b* by the link *c* and the lever *d*. This conoid, in conjunction with the cone-shaped chamber *e* in which it is placed, controls the action of the governor. A rocker-arm *f* is pivoted on a pin *g* which has its bearings in the governor casing. One end of this rocker-arm rests on the top of the conoid *a* and the other end rests on a small disk on top of the compression spring *h*. The spring *h* holds the conoid in a wide open position until the velocity of the charge passing from the carbureter to the engine becomes great enough to overcome the resistance of the spring, when the conoid will rise in the cone *e* and close the butterfly valve to which it is connected. A decrease in engine speed occasioned by an increased engine load, would result in a decreased gas velocity and a consequent lowering of the conoid in the cone, and the placing of the throttle valve in a more nearly open position.

The butterfly valve *b* is carried on a shaft *i* which works in the bronze bushings *j*. The shaft on which the hand-control lever *k* is mounted works independent of the shaft on which the butterfly valve is mounted, motion between the two shafts being affected by means of the clutch *l*. Due to the construction of the clutch, the control lever *k* has no action in mechanically opening the butterfly valve, this being accomplished only by the action of the spring *h*, but can be used to bring the valve to a closed position.

The plunger *m* is cushioned on the so-called bumper spring *n*, and is operative only when the butterfly valve approaches very closely a closed position. The spring *n* is an auxiliary to the main spring *h* to counteract the increased vacuum caused by bringing the throttle toward a closed position.

The governor is placed between the intake manifold and the carbureter, from which the regular throttle has either been

removed or has been locked in its wide-open position. The Monarch governor cannot be used with any carbureter in which the quality of the mixture at different speeds is mechanically controlled by the carbureter-throttle position.

70. The operation of the Monarch governor is as follows: At low and medium engine speeds the engine control is entirely by the throttle lever *k*, Fig. 34, but at high speeds the impact of the fresh charge coming from the carbureter against the conoid *a* is sufficient to overcome the tension of the coil spring *h*, and the conoid *a* moves upwards, thus partly closing the throttle valve *b* even though the throttle lever *k* is moved to its wide-open position. By thus restricting the flow of the mixture to the engine the speed of the latter is prevented from exceeding that for which the governor has been set.

The Monarch governor is set at the factory, by adjusting the tension of the coil spring, for a maximum speed of 1,000 revolutions per minute; the adjusting nut *o* is then locked with a padlock *p*, the key of which is supposed to be kept by the owner of the truck, in order that the driver cannot tamper with the adjustment. By removing the padlock, the spring tension can be changed by turning the nut *o* in or out to increase or decrease the engine speed. Having no exterior drives of any kind, the installation of the Monarch governor is possible on practically any make of internal combustion engine.

71. Fig. 35 (*a*) shows in perspective and view (*b*) in cross-section a *Pierce centrifugal governor,* made by the Pierce Governor Company, Anderson, Indiana. Such a governor is placed between the intake manifold and the carbureter. It can be used with any design of carbureter, and can be applied to control the engine speed in all gears on which the vehicle is driven, or to control the vehicle speed in high gear by limiting the engine speed for the high-gear drive alone. To control the engine speed alone, the governor is driven directly by the engine; to control the vehicle speed, the governor is driven from a front wheel or from the transmission.

The governor consists of a casing *a* containing the actuating parts and a valve box *b* containing the butterfly governor

valve *c* that regulates the flow of the fresh charge to the cylinders entirely independent of the carbureter throttle. The actuating parts of the governor are the governor weights *d*, the plunger *e*, the drive shaft *f*, the spring *g* the tension of which is adjustable by means of the adjusting screw *h* and spring holder *i*, and the push-rod *j* coupled to the crankpin of a small crank *k* fastened to one end of the governor-valve shaft.

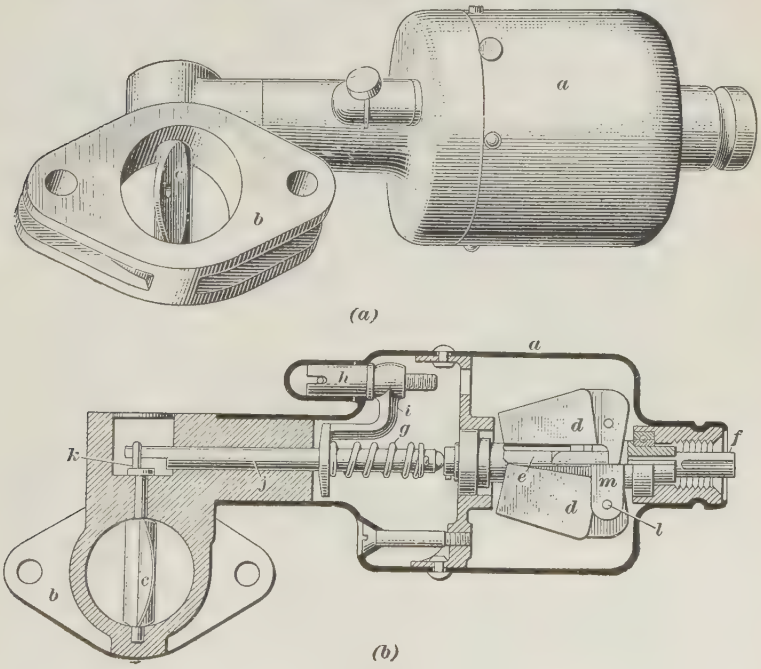

FIG. 35

The governor weights are hinged at *l* to a spider *m* which is free to revolve on ball bearings and is driven by the drive shaft *f*.

72. With the drive shaft at rest, the weights *d* occupy the position shown and the governor valve *c*, Fig. 35, is wide open. With the drive shaft running, the weights *d* revolve with the spider *m* and they tend to swing outwards around their hinge pins *l* under the influence of centrifugal force. Their outward

motion is resisted, however, by the initial tension of the spring g, and the weights d therefore do not move outwards until the speed has become high enough for the increasing centrifugal force to overcome the initial spring tension; when this occurs, an arm on each weight d presses the plunger e and push-rod j

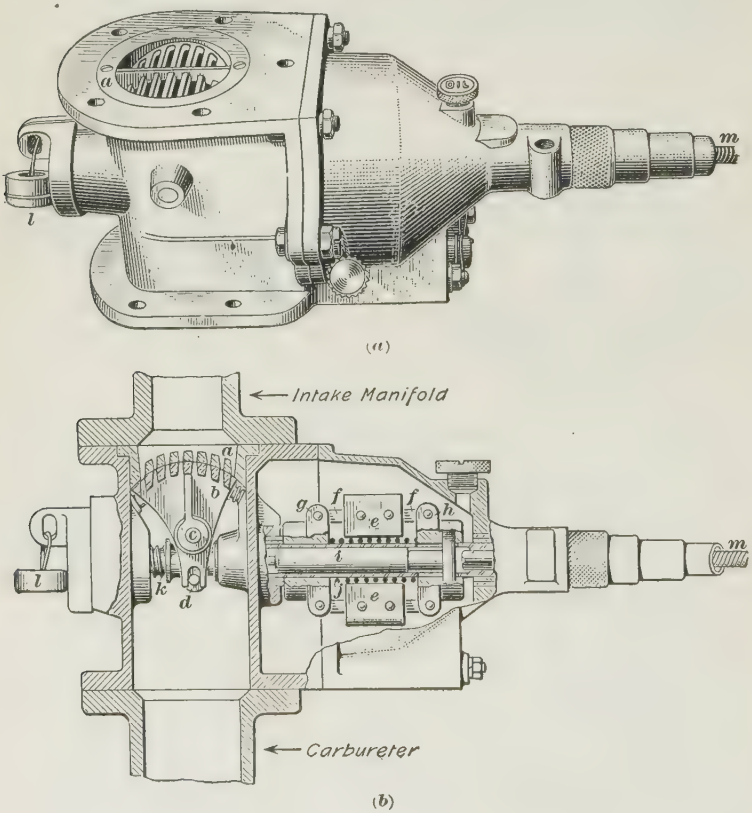

FIG. 36

to the left, thereby compressing the spring until the resistance of the spring just equals the centrifugal force of the weights. This partly closes the governor valve c. The weights d remain in their position as long as the governor drive-shaft speed does not change; with every increase of engine speed they move out farther, thereby still more closing the governor valve, until a

point is reached where this valve so restricts the flow of gases to the engine that any further opening of the carbureter throttle does not produce a higher engine speed. Conversely, if the drive-shaft speed is reduced, the governor valve automatically opens to correspond.

The Pierce governor is usually set at the factory to permit a maximum engine speed of about 1,000 revolutions per minute, and the adjustment is then sealed. The speed of the engine at which the governor operates can be changed by cutting the seal wire, pulling off the cap over the adjusting screw *h*, and turning the screw clockwise to reduce the engine speed and counter-clockwise to increase the engine speed.

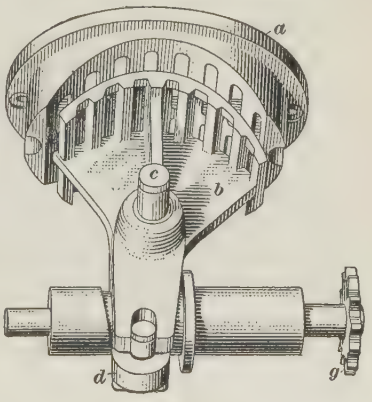

FIG. 37

73. The *simplex governor,* made by the The Duplex Engine Governor Company, Brooklyn, New York, is of the centrifugal type, is placed between the inlet manifold and the carbureter, and uses a rotary gridiron valve instead of a butterfly valve for limiting the engine speed. It can be driven by the engine itself, in which case it limits the engine speed on all gears on which the vehicle is driven, or it can be driven from the vehicle, when it limits the vehicle speed by limiting the engine speed in high gear.

A perspective view of a Simplex governor is shown in Fig. 36 (*a*) ; a cross-sectional view is presented in (*b*), and a view of the valve seat and gridiron valve, removed from the governor, in Fig. 37. The same parts have been given the same reference letters, as far as possible, in the three illustrations. The valve seat *a* has straight slots, its lower face being circular ; the gridiron valve *b* has similar straight slots, is curved to fit the valve seat, and is hung on trunnions *c* so that it can rock. A forked projection at the lower end of the valve *b* fits over a

pin carried by the longitudinally movable collar *d*. When the slots in the valve seat and valve register, there is a full flow of the fresh charge to the engine; when the collar *d* moves to the left (this is accomplished by the governor weights under the influence of centrifugal force), the slots of the valve seat are partly closed and the flow of fuel to the engine is restricted so that it cannot exceed the speed for which the governor is adjusted. The rotating parts of the governor consist of four weights *e* mounted on two links *f* for each weight; the one set of links is mounted on pins of a spider *g*, which rotates but is fixed lengthwise, while the second set of links *f* is hinged to a collar *h*, which rotates but can move lengthwise. The movement of the collar *h* to the left is transmitted by the plunger *i* to the collar *d*, thus rocking the gridiron valve *b* and thereby partly closing the openings through the valve seat *a*. Outward motion of the weights *e* is resisted by the helical springs *j*, *k*, which have been given a sufficient initial tension to prevent the centrifugal force of the revolving weights from overcoming it until the governor reaches very nearly the speed it is set for. The tension of the spring *k* is adjustable, the adjustment being locked by a seal *l*.

The rotating parts of the governor are driven from the engine or the vehicle by a flexible shaft *m*, and sometimes by rigid shafting and gearing, the purpose in either case being a positive drive.

74. The centrifugal governors thus far described, when driven directly by the engine, as previously explained, limit the engine speed to the same maximum, no matter in what gear the vehicle is driven. This method of control is open to the objection that it prevents the exerting of the full engine power on low or intermediate gear when it may be needed to meet extraordinary road conditions, such as extricating the vehicle from a mudhole under its own power. When the governor is driven by the vehicle itself, it limits the engine speed on high gear, but exercises no control over the engine when in intermediate or low gear, permitting the driver to race the engine disastrously.

To overcome these drawbacks of the centrifugal governor driven either by the engine or by the vehicle, the makers of the Simplex governor have brought out the *Duplex governor,* which has two separate drives, the one being from the engine and the other from the vehicle on high gear. The construction of the governing elements of the Duplex governor is no different from that of the Simplex; there are two drive shafts, however, which can be seen at *a* and *b* in Fig. 38, which shows a Duplex governor partly disassembled. The shaft carrying the revolving weights *c* has fastened to it a gear *d* which meshes with two gears *e, f* driven by the shafts *a, b.* The gears *e, f* are not fastened to the shafts *a, b,* but are so arranged that

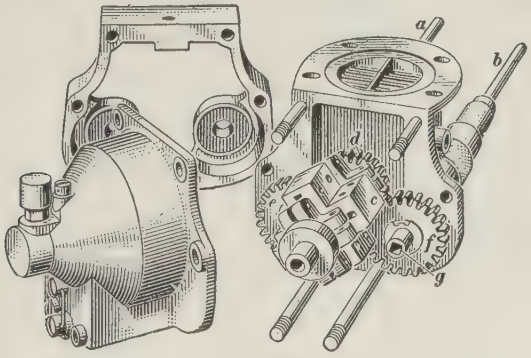

FIG. 38

they can be driven only in one direction by the shafts, an overrunning clutch *g,* sometimes called a one-way clutch, being arranged on each shaft. It is an inherent property of a one-way clutch that the outer member can turn in only one direction when driven by the clutch, but releases itself from the clutch and can turn faster than this, in the same direction the outer member was driven.

75. In studying the action of the Duplex governor, it must be borne in mind that the governor acts on the governor valve at a certain speed of rotation of the governing elements, no matter at what rate of speed in reference to the engine or vehicle speed it is driven. This fact is made use of by gearing the governor to the engine so that the governor reaches its

governing speed at, say, 1,500 revolutions per minute of the engine, and gearing the governor to the vehicle propeller shaft so that the governor reaches the same governing speed at 1,000 revolutions per minute of the engine. Then, if the vehicle is in high gear, the drive shaft geared to the propeller shaft runs faster than the drive shaft geared to the engine, the overrunning clutches permitting the one shaft to run faster than the other by slipping in one of the gears *e, f,* and the engine speed is limited to 1,000 revolutions per minute, which in turn limits the vehicle speed. Now suppose the vehicle is driven in low gear; the propeller shaft then turns slowly and hence the drive shaft geared to it also turns slowly, in fact more slowly than the governor drive shaft geared to the engine. Therefore, the governor drive shaft geared to the engine now runs faster than the other drive shaft, and drives the governing elements, and permits these to limit the engine speed to 1,500 revolutions per minute. In any case the one of the two governor drive shafts that has the higher speed governs automatically the highest engine speed, which, as previously stated, is different for the two drives.

AUTOMOBILE CARBURETERS

FUELS AND FUEL TANKS

COMBUSTIBLE MIXTURES

DEFINITIONS

1. A body that at ordinary temperatures is a solid or a liquid, but becomes a gas under certain conditions, is said to be a **vapor** when in this gaseous state. When such a vapor can be ignited and burned, it is called a **combustible vapor.** If a combustible vapor and air are mixed in proper proportions and ignited, the combination of the gas with the oxygen of the air is so rapid as to produce an **explosion,** which may be defined as an extremely rapid combustion accompanied by the formation of gases and increased pressure. The sudden rise of pressure produced is made available for driving internal-combustion engines, of which the automobile engine is one type.

2. A mixture of two or more substances whose chemical combination will cause an explosion is called an **explosive mixture.** Examples are mixtures of gasoline vapor and air ranging in the proportions of 5 parts to 12 parts of gasoline vapor to 100 parts of dry air, by weight, any such mixtures giving regular firing in an engine.

The enriching of air, as by adding to it the vapor of gasoline, kerosene, alcohol, etc., is called **carburation** of the air; the device used for carburating the air is called a *carbureter.* The

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mixture formed is variously called the *combustible mixture,* the *gas,* or simply the *mixture.*

3. The operation of setting fire to the gaseous mixture in the engine cylinder by means of a device called an *igniter* or a *spark plug* is known as **ignition.** The moment that ignition begins is called the *time of ignition.* The quantity of the mixture of gas and air taken into the cylinder at one time is called the **charge,** and when all of it is ignited, it is said to be *wholly inflamed.* The time elapsing between the time of ignition and the moment when the gas is wholly inflamed is known as the *duration of inflammation,* or duration of the explosion. The velocity with which the flame is generated in the charge is called the *rate of flame propagation.*

4. Matter is anything that occupies space; it is the substance of which all bodies consist, and is composed of *molecules* and *atoms.* A **molecule** is the smallest portion of matter that can exist without changing its nature; an **atom** is an indivisible portion of matter. Atoms unite to form molecules, and a collection of molecules forms a *body.*

Every body is either an *element,* a *compound,* or a *mixture.* If a body cannot be separated by any known processes into other substances, it is called an **element.** Iron, gold, sulphur, hydrogen, and oxygen are some of the elements. When a body can be divided into other substances, it is called a **compound.** Thus, water may be divided, or *decomposed,* into two gases, namely, hydrogen and oxygen, that are entirely unlike and neither one of which resembles the water from which it is produced; hence, water is a compound. Two or more elementary substances may be mixed together and yet not combine to form a new substance. They are then said to form a **mixture.** The mixture has the properties of the elements composing it. The most familiar example of a mixture is ordinary air. It is composed of oxygen and nitrogen, 23 parts, by weight, of the former, to 77 parts, by weight, of the latter. The two gases do not combine chemically; they are simply mixed.

COMBUSTION

5. The internal-combustion engine used on automobiles burns the fuel inside the engine, as the name indicates. The fuel used is generally gasoline; and, in rare cases, kerosene. These fuels are liquids in the commercial form. The burning, or combustion, of the fuel liberates *heat,* which is a form of energy. The function of the engine is to convert some of this heat energy into mechanical energy, which can be utilized to perform the work of driving the car.

6. The atoms of some of the elements have a very great affinity, or attraction, for those of other elements, and when they combine, they rush together with such rapidity and force that heat and light are produced. This rapid chemical combination is called *combustion.* Oxygen, for example, has a great attraction for nearly all the other elements. An atom of oxygen is ready to combine with almost any substance with which it comes in contact. For carbon and hydrogen, oxygen has a particular attraction, and whenever these elements at a sufficiently high temperature come in contact with oxygen, they combine with great rapidity. The combustion in an automobile-engine cylinder is of this nature. The temperature of a small part of the mixture of gas and air is raised by an electric spark, and then the fuel charge begins to combine with oxygen taken from the air. The combination is so rapid and violent that a great quantity of heat is given out, and this heat suddenly raises the temperature of the mixture. **Combustion,** *therefore, is the rapid chemical combination of two or more substances, resulting in the production of heat.*

7. Ordinarily it is necessary to start combustion by bringing some part of the substances to the temperature of combustion. In the case of combustible vapors in automobile engines, the heat for ignition is derived from an electric spark. The electric spark, although very small, is of a very high temperature, and is amply sufficient for the purpose, provided the proportions of the combustibles and the oxygen adjacent to the spark, are approximately those required for chemical union.

A strong spark, however, will cause a more rapid spread of the flame than a weak spark.

8. The gases produced by, or remaining after, combustion in an automobile-engine cylinder, are known as the **products of combustion,** frequently called the *exhaust gases,* or simply the *exhaust.*

All the fuel oils and gases are chemical compounds of hydrogen and carbon, and are called *hydrocarbons.* When burned in oxygen, they split up, the hydrogen and carbon uniting separately with the oxygen in the air and producing water vapor and carbon dioxide, respectively. When carbon and oxygen combine, they form carbon dioxide; when hydrogen and oxygen combine, they form water. When, as is ordinarily the case, the oxygen is obtained from the air, the nitrogen of the air passes into the engine cylinder along with the oxygen. It takes no part in the combustion and passes off through the exhaust with the carbon dioxide.

9. The gases produced by the combustion of any of the combustible mixtures such as are herein mentioned contain some steam as the result of the chemical combination that takes place between the oxygen of the air and the combustible elements of the fuel. There is ordinarily some moisture in both the air and the gas or vapor, and this moisture is changed into steam by the heat of combustion. If the gaseous products are cooled somewhat, the steam may condense into the form of water.

This accounts for the fact that water in small quantities is often found in the crankcases of automobile and motor-truck engines, especially in cold weather; this water is simply steam condensed in the crankcase after having worked past the pistons of the engine.

The heat resulting from burning a gaseous combustible mixture increases the volume of the gas if the pressure is kept constant, as when the mixture is burned in the open air; but if the mixture is confined in a closed space, so that the gases cannot expand, the burning increases the pressure against the walls of

the enclosing vessel. As the gases cool after burning at constant pressure, the volume contracts. In the case of constant volume, the pressure falls as the temperature decreases.

FUELS

10. Gasoline.—All automobile and similar internal-combustion engines employ a liquid hydrocarbon fuel, that known under the general trade term of *gasoline* being most generally used. Most of the gasoline is obtained by the distillation of crude oil; some gasoline, known to the oil trade as *casing-head gasoline*, is extracted by various processes from natural gas. Casing-head gasoline has a very high volatility, but can be purchased only in a few localities; in practice nearly the whole output is mixed at the refineries with low grades of gasoline to make a suitable motor fuel.

While the commercial gasoline sold as motor fuel today has a much lower rate of evaporation than was formerly the case, yet in modern carbureters, mixing it with heated air, and in many cases sending the combustible mixture through heated manifolds to the engine, it gives good results after the engine has warmed up.

11. Gasoline is particularly adapted for use in automotive engines on account of its fairly high evaporative rate at moderate temperatures, evaporation being an essential to thorough mingling and complete combustion of the charge in the limited time available. The term *automotive engine* includes all internal-combustion engines used in self-propelled vehicles, such as tractors, trucks, automobiles, fire engines, etc. Gasoline is not, however, a substance having a definite chemical composition, but a mixture of various substances having different evaporative rates. At low temperatures, certain of these substances are not readily vaporized so as to give their maximum effect in the engine. In fact, vaporization is sluggish even at moderate temperatures, owing to the cooling effect of the evaporative process not only on the charge passing to the cylinder, but also on the carbureter and intake pipes. This is

illustrated on starting a cold engine in cold weather, when a considerable excess of fuel makes starting easier. The excess is required because only the lighter parts of the fuel are evaporated at that temperature and are available for ignition, the heavier parts being inert.

12. Gasoline varies considerably in quality. A poor quality of gasoline makes it difficult to start an engine, especially when the gasoline is cool. In fact, gasoline of poor quality has more the nature of kerosene, which does not vaporize readily, even at the temperatures of summer weather. A good quality of gasoline, however, contains constituents that vaporize readily at a temperature as low, or even lower, than the freezing point of water; that is, as low as 32° F.

13. *Stale gasoline* is the name quite frequently applied to gasoline that does not vaporize readily. If a good grade of gasoline is left standing in an open vessel, the more volatile, or lighter, part of it will vaporize rapidly, leaving the heavier, or less volatile, part that constitutes stale gasoline, which is of the same nature as a low grade of gasoline.

In the early history of the automobile, the standard quality of gasoline was kept fairly close to that which was known as *76° gasoline*. This designation of the quality comes from the use of a Baumé hydrometer to test the heaviness of the gasoline.

14. At present the automobile user has very little choice as to the quality of the gasoline he buys. With rare exceptions, the only gasoline that is readily available is that sold under the trade name of *auto gasoline,* which has a heaviness ranging somewhat near 60° on the Baumé hydrometer, but often is much lower. As a general rule, the better grades of gasoline are not carried in stock and can be obtained only on special order directly from the refineries.

The present low-grade gasoline has increased the difficulty of starting engines fitted with the older forms of carbureters that were designed for the higher grades of gasoline readily available everywhere at the time these carbureters were built.

However, practically all modern cars have their engines equipped with carbureters and carbureter auxiliaries designed to handle the low-grade gasoline now on the market, and no particular difficulty is experienced under this condition in starting the engine, although it will be slightly harder than with a high-test, and hence more volatile, gasoline.

15. The heaviness of gasoline compared with that of water is measured by means of a hydrometer graduated to the arbitrarily chosen Baumé scale, in which the higher the numerical value the lighter is the gasoline.

A Baumé scale hydrometer made especially for testing gasoline is shown in Fig. 1. It consists of a glass tube, near the bottom of which are two bulbs. The lower and smaller bulb is loaded with mercury or shot, so as to cause the instrument to remain in a vertical position when placed in the liquid in the vessel *a*. The upper bulb *b* is filled with air, and its volume is such that the whole instrument is lighter than an equal volume of water. When placed in gasoline, or any other liquid, the hydrometer sinks so that the upper bulb and part of the graduated neck, or stem, is beneath the surface. The reading on the neck at the point where it emerges from the surface of the liquid indicates the *degrees,* as they are called, or the heaviness, of the liquid. The farther the hydrometer sinks into the liquid, the higher is the numerical reading on the scale. The instrument, of course, will sink farther into a light liquid than into a heavy one.

Fig. 1

The hydrometer shown in Fig. 1 reads down to 60 degrees, but lower reading instruments are in the market.

Gasoline, like any other liquid, is heavier when it is cold than when it is warm. Therefore, a gasoline that gives a reading of 62° on the hydrometer on a summer day, when the thermometer indicates a temperature of, say, 80° F., will give a lower reading on a winter day when the gasoline is as cold as the freezing point of water.

16. It is assumed by many persons that a Baumé scale test indicates infallibly the quality of the gasoline. Such is

not the case, however, as oil refineries can and do produce gasoline of any desired Baumé scale indication by mixing together light and heavy hydrocarbons in suitable proportions. The real quality of a gasoline cannot be determined by any simple test; the test requires the services of a skilled chemist having proper equipment.

17. Kerosene.—At present, kerosene, which is one of the heavier distillates of crude oil, is not used to any extent in automobile engines, although it is sometimes employed as a fuel for tractor engines. So far as their heating value per pound is concerned, there is not much choice between kerosene and gasoline, each developing about 19,800 British thermal units per pound. Kerosene, however, is about 10 per cent. heavier, so that a gallon of kerosene has greater fuel value than a gallon of gasoline.

Ordinary kerosene varies from 54° to 40° Baumé. Exceptionally light kerosene, such as the Pennsylvania light oil, will test about 54° Baumé.

Since kerosene is much heavier than gasoline, it does not vaporize so readily as gasoline; hence, it is very difficult to start an engine fitted with a regular gasoline carbureter by using kerosene as a fuel. In order to produce a homogeneous mixture of kerosene and air, the former must be broken up into a very fine spray before mixing it with the air, and to assist the vaporization of this spray the kerosene must be heated to a fairly high temperature. This may be done by leading the exhaust gases around or through the carbureter. At present there is little demand for a kerosene carbureter for automobile engines, but should gasoline become so scarce that its price would tend to prohibit its use as a motor fuel, there is little doubt that kerosene carbureters will be placed on the market by many manufacturers.

18. Benzol.—The combustible liquid known as *benzol* is a by-product obtained in the manufacture of coke and illuminating gas; it is also produced by distillation from coal tar. The supply of benzol is very limited. Only about 3 gallons of it is obtained from every ton of coal converted into coke or

used in gas making. At present, benzol is used in the United States only to a very limited extent in automobile work, as it can be procured in only a very few places.

Benzol is about the color of water; while it is not so volatile as gasoline, it is claimed that an internal-combustion engine fitted with an ordinary gasoline carbureter can be started practically as easily on benzol as on gasoline.

19. Vaporization of Liquid Fuels.—To produce combustion, combustible liquids must first be vaporized and their vapors mixed with air in suitable proportions. This process requires the addition of heat, which may be secured by absorption or by radiation from surrounding objects, and which will come mainly from the combustion itself after that has been started. Liquids that vaporize at ordinary temperatures are highly dangerous if their vapors are inflammable, and should be handled with extreme care. If, like kerosene and the heavier oils, they do not vaporize at ordinary temperatures, they are not so dangerous.

In automobile practice, the liquid fuel is vaporized before it enters the space where it is burned. The vaporization is accomplished by bringing the liquid into intimate contact with air. When the air and fuel vapor are thus mixed together in proper proportions, the mixture can be ignited and burned by the application of a lighted match, an electric spark, or any sufficiently hot substance, as a piece of red-hot metal.

The vapor of any of the liquids used as a motor fuel can be considered to be a gas so far as its use in the engine is concerned. In fact, illuminating gas is frequently made by mixing the vapor of gasoline with air, the proportion of the vapor being so great that the mixture will not burn until more air is added to it. This gasoline gas is carried through pipes and burned in the same manner as ordinary illuminating gas made from coal.

20. The gasoline available today cannot be completely vaporized even by mixing it with air heated to as high a temperature as practical considerations permit in automobile work, as some of the heavier hydrocarbons in it have a temperature

of vaporization considerably beyond that of the heated air. This fact has led to the design of exhaust-heated intake manifolds, combined intake and exhaust manifolds, and hot-spot manifolds, the idea being to apply as much heat as possible to the incoming fresh charge to insure a more complete vaporization of the gasoline. The heating of the incoming fresh charge causes this to expand and become lighter, thereby causing a smaller weight of fresh charge to be taken into the cylinders; this means in turn a theoretical decrease in the maximum power developed by the engine. Yet, in practice it is found that owing to the better mixture produced by the heating of the fresh charge no appreciable power decrease can be noted.

MIXTURES OF GASOLINE AND AIR

21. In considering the following discussion, it will be well to bear in mind that gasoline is a name commercially applied to a rather wide range of combustible liquids distilled from crude oil. The proportions of air and gasoline must be kept within a limited range in order to obtain the best results in the engine.

A given volume of air can absorb only a certain amount of gasoline vapor, just as water can dissolve no more than a certain amount of salt; the air is then said to be *saturated* with gasoline vapor. A mixture containing less than this amount of vapor is neither a saturated nor a perfectly proportioned mixture; the less vapor it possesses, the *leaner* it is said to be. A mixture containing more than this amount of vapor is not a perfectly proportioned mixture either; the more vapor it has, the *richer* it is said to be. The proper mixture of gasoline and air for explosive purposes in a gasoline-engine cylinder burns, at atmospheric pressure, with a blue flame, and leaves little or no sooty, or carbon, deposit on the walls of the vessel in which it may be burned. Lean mixtures behave in the same way, except that when they burn in a confined space, the pressure produced is less than that produced by a perfect mixture. The surplus air does not burn; it is heated, however, and, of course, expands some. A more intense explosion will be pro-

duced by a proper amount of gasoline vapor and air if the two are first thoroughly mixed together.

22. If there is present in a mixture more gasoline vapor than the air present can take up, and the mixture is ignited, a certain amount of the vapor will be consumed, leaving the surplus unconsumed. Inrushing fresh air may mix with the vapor thus left over, and another explosion may result if there is a flame present or if the material it comes in contact with is hot enough to ignite it. A mixture as rich as this burns under atmospheric pressure with a yellowish flame and leaves a sooty, or carbon, deposit.

Under all requirements, whether of economy or of power, an intimate and uniform mixture is essential, and this should be obtained before the charge is fired. This means early and rapid vaporization, particularly at high engine speeds, and this can only be obtained in practice by bringing the incoming fresh charge into contact with exhaust-heated suitably arranged surfaces.

23. As gasoline vapor is heavier than air, it tends to sink to the bottom of a vessel containing it, and unless agitated it mixes but slowly with the air above it. For this reason, a room in which gasoline vapor is present cannot be well ventilated by openings near the ceiling; but openings through the floor or under a door will allow the vapor to pass out. The room can also be ventilated by a flue whose bottom opening is at the floor, provided there is a current of air passing upwards through the flue. If the flue has no draft, as may be the case in damp weather, some artificial means, such as a fan or a coil of steam pipe, must be used to induce it.

24. Economy requires that, at the time of ignition, each particle of fuel shall be in contact with its proportion, or more than its proportion, of air. On the other hand, maximum power in an engine of definite size is obtained by burning the greatest practicable amount of fuel, and, consequently, by supplying fuel somewhat in excess of the chemical combining proportion, in order to utilize the limited cylinder capacity to its fullest extent. This agrees with the experience of practical

motorists, who know that an excess of gasoline is required for easy starting, a rather rich mixture for extreme power, and a weaker mixture for economy. An excess of fuel is, to an extent, a corrective for imperfect mixing and gasifying of the charge.

FUEL SUPPLY

INSTALLATION OF SUPPLY SYSTEMS

25. The tank that carries the supply of liquid fuel for an automobile may be located either at a level considerably higher than the carbureter, so that the liquid will flow freely, or at a level lower than the carbureter, so that there will be no gravity flow to the latter even when the tank is full. When the tank is placed lower than the carbureter, pressure must be used to force the liquid out of the tank and into the carbureter, or into an auxiliary tank above the level of the carbureter. A tank in which pressure is used is called a *compression tank* or *pressure-feed tank*. If the tank is located above the carbureter, it is called either a *gravity tank* or a *gravity-feed tank*. Occasionally a tank is located above the carbureter, and yet, to insure a flow of the fuel to the carbureter under all conditions, air or gas pressure is employed to force the fuel to the carbureter; this practice is not found in modern cars, however.

The most common practice today is to use a large supply tank at the rear, and to use a small auxiliary tank under the hood above the carbureter level, to which tank fuel is forced periodically by the pressure of the atmosphere, and from which auxiliary tank the fuel flows to the carbureter by gravity. As the fuel flow to the auxiliary tank is induced by creating a partial vacuum, this method is known as the *vacuum fuel feed*.

26. As a general rule gravity tanks (excluding auxiliary vacuum-feed tanks) are located in the cowl, with a filler opening on the cowl board, the tank being placed as high up as conditions permit, to insure a full flow of gasoline to the carbureter on ascending the steepest hill. In the model T Ford

cars, and a few other cars, the gravity tank is located under the front seat.

Cowl tanks are usually shaped as closely as possible to fit the space under the cowl, so as to give a large fuel capacity.

Tanks that are placed under the front seats of automobiles are either rectangular or cylindrical in shape; they may be made long enough to fill entirely the space beneath both of the front seats, thus giving a large fuel capacity. In many cases, rectangular fuel tanks occupy only part of the space available

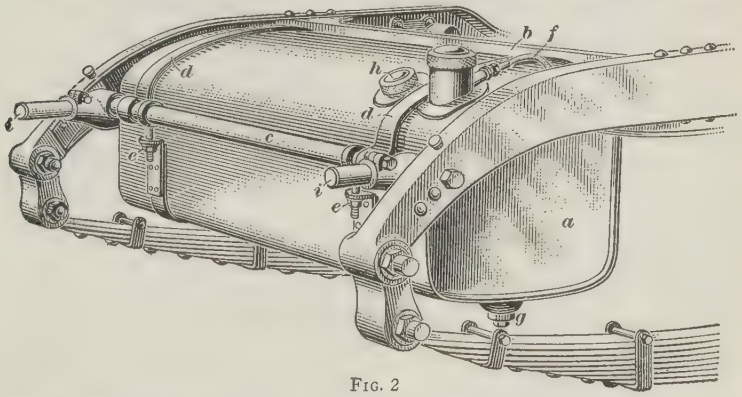

FIG. 2

under the front seats, thus leaving some spare space in which to store tools, supplies, or tire chains. As a general rule, when a fuel tank is located underneath the front seat, it is necessary to remove a seat cushion to give access to its filler opening.

Pressure-feed gasoline tanks are usually carried at the rear of the car, being swung from special brackets extending from the frame; they then extend crosswise of the car and are placed between the rear springs and back of the rear axle.

27. Fuel tanks that are placed at the rear of the car may have any shape dictated by the fancy of the designer; the majority of them, however, are approximately rectangular in cross-section. In order to give free access to the rear axle, rear fuel tanks are usually so mounted that they can be quickly and easily removed.

A typical installation of a rear fuel tank is shown in Fig. 2, which illustrates the practice followed in some eight-cylinder

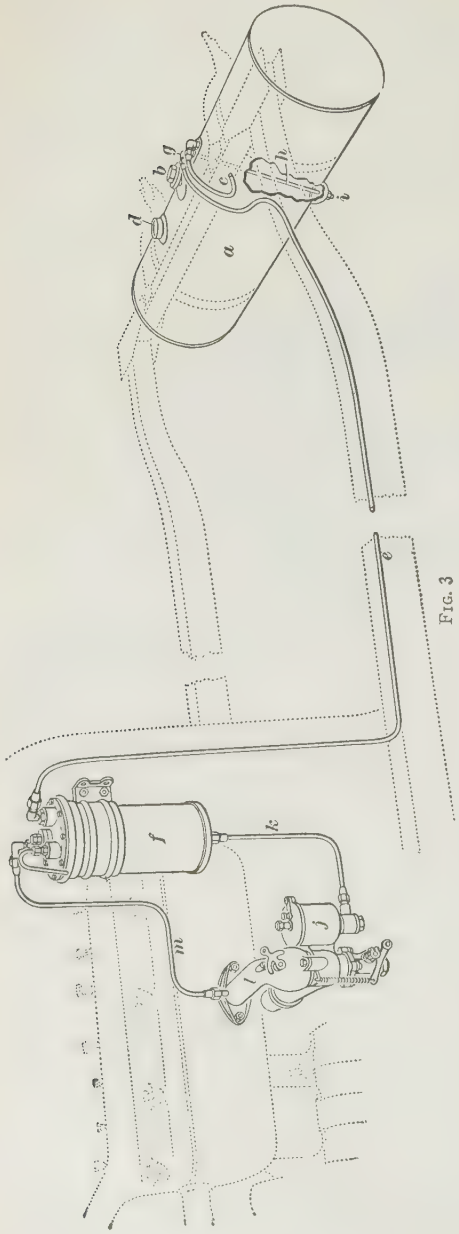

FIG. 3

Cole cars. The tank *a* is supported from a channel-shaped cross member *b* and tubular cross member *c* by steel supporting straps *d*, which are lined with brake lining to prevent chafing holes through the sides of the tank. The lower half of each supporting strap can be quickly swung out of the way to permit removal of the tank, by removing the nuts *e*. As this tank is used with a vacuum feed, there is only one pipe connection *f* to the vacuum tank; in this case the pipe *f* enters the side of the filler funnel and drops down to near the bottom of the tank. A drain plug *g* is placed in the base of the so-called *sediment chamber*, in which water and dirt in the fuel collect. A gasoline gauge *h* shows the amount of fuel in the tank. With a rear tank used with a vacuum tank it

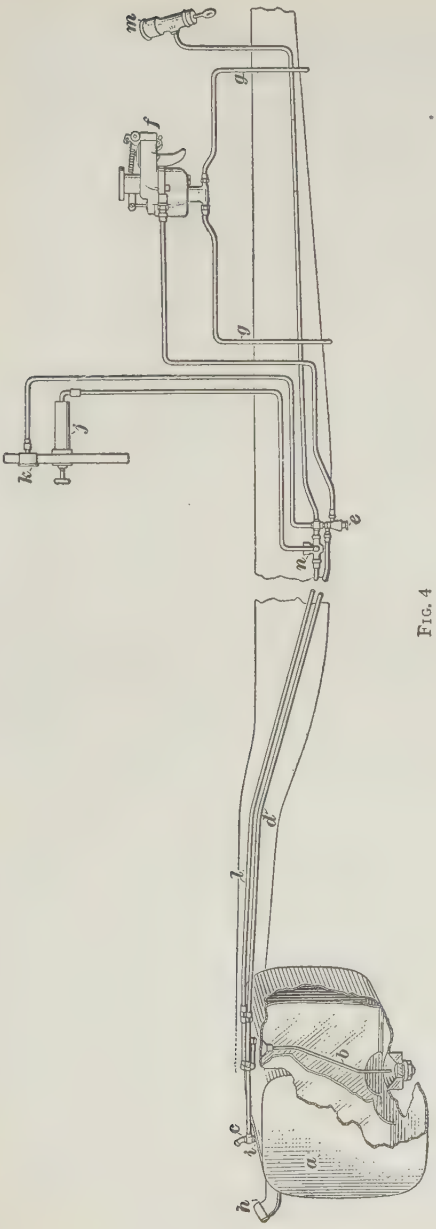

FIG. 4

is very necessary to have a small opening in the filler cap, to admit air to the tank.

The cylindrical projections *i* receive the spare-tire carrier, which is not shown.

28. The entire fuel feed system installation with a vacuum feed and a rear tank, as installed in Dodge Brothers motor cars, is shown in Fig. 3 in the position actually occupied in the cars. The main fuel tank *a* in this case is cylindrical, is made of pressed steel, and is supported from the rear of the frame. The tank has a filler cap *b* and an air vent pipe *c* through which the tank is open to the atmosphere; it is also fitted with a gasoline gauge *d*. The fuel is periodically forced by the pressure of the atmosphere through the pipe *e* to the top of the auxiliary, or *vacuum, tank f*; this tube connects to the fuel tank outlet elbow *g* and draws its fuel supply from the bottom of the tank *a*

through the tube *h*, which dips partly down into the sediment bowl *i*. The object of drawing the fuel upwards out through the top of the tank is to prevent sediment being drawn into the tube *e*; there are some cars, however, in which the fuel pipe attaches to the bottom of the tank. The bottom of the vacuum tank *f* contains the fuel supply for the carbureter, which supply passes to the float chamber *j* through the pipe *k*. The carbureter inlet *l* to the inlet valves is connected by the vacuum tube *m* to the top of the vacuum tank *f*. The construction and operation of the vacuum tank is described in detail further on.

29. The installation of a rear tank with a pressure fuel system, as used in eight-cylinder Cadillac cars, is shown in Fig. 4, with the parts in approximately the relative positions they occupy in the car. The fuel tank *a* is nearly rectangular in this case, and is shown partly cut away in order to exhibit clearly the internal feed pipe *b* dipping partly into a sediment cup which is fitted with a drain plug on the bottom. The gasoline pipe *b* is connected to a shut-off valve *c* on top of the tank, from which the fuel pipe *d* runs first to a gasoline strainer *e* and thence to the carbureter *f*. This carbureter is fitted with two drain pipes *g* to carry off any gasoline dripping from it. The tank itself has a filler opening *h* closed by an air-tight filler cap, and a gasoline gauge *i*. Gasoline is forced to the carbureter by air pressure pumped up at first by hand by the hand air pump *j*, the air pressure being shown on the air-pressure gauge *k*, and the air passing through the pipe *l* into the top of the tank *a*. When the engine is running, the air pressure is maintained by an engine-driven air pump *m*; and a pressure-relief valve *n*, set to open at about 4 pounds per square inch pressure, prevents pumping up a higher pressure.

In some pressure-feed fuel systems the relief valve forms an integral part of the engine-driven air pump. In some of the older cars with pressure fuel feed only a hand pump was employed.

GRAVITY-FEED FUEL SUPPLY

30. The gravity system of feeding gasoline to the carbureter otherwise than from an auxiliary tank requires very little attention and no maintenance of air pressure by means of a hand pump or other device; hence, it is very simple. There must always be a small opening in the upper part of a gravity tank, so that air can pass into the tank as the fuel flows out; otherwise, a partial vacuum will be formed in the tank and the flow of fuel will gradually decrease until the carbureter does not receive enough to keep the engine running. The smaller the air space in the upper part of the tank, the shorter is the time required for this to occur. Only a small vent hole is needed to allow the air to pass in. It is seldom advisable, however, to make the hole smaller than $\frac{1}{16}$ inch in diameter. If made smaller, it is liable to become clogged, which condition is the same, so far as the outflow of gasoline is concerned, as if there were no vent in the tank. As a general rule, the vent hole is drilled in the center of the filler cap.

31. A gravity tank may be placed high enough above the carbureter for satisfactory operation on level roads and slight grades, but the tank may be too low for good operation when ascending very steep grades. Under such conditions, a small particle of foreign matter that would cause no trouble on level roads or slight grades may partly clog the gasoline pipe leading to the carbureter and thereby starve the engine just when hard work is required of it. One way to remedy trouble of this kind is to shut off the gasoline at the tank and then disconnect the supply pipe from the carbureter; a rubber tube attached to the tire pump may then be applied to the supply pipe. Air should then be pumped through the pipe until the particle is dislodged.

The farther back the gravity tank is placed from the engine, the greater will be the change in level of the gasoline in the carbureter and tank for a given increase in the grade.

32. The greatest present-day objection to gravity fuel feed is that it requires placing the carbureter very low in respect to

the inlet valves to insure a steady fuel supply on steep grades. This, on account of the only available supply of gasoline having a low volatility, causes a great condensation in the necessarily long intake manifold, and not only prevents proper gasoline economy, but also interferes with obtaining a proper mixture. In fact, the operation of many old cars can be greatly improved by placing the carbureter as high as possible and using either a vacuum feed or a pressure feed, preferably supplemented by exhaust-jacketing the intake manifold and preheating the air supply.

PRESSURE-FEED FUEL SUPPLY

33. In all pressure tanks, after the tank has been filled with fuel, air must be pumped in by hand until the pressure is sufficiently high to force gasoline to the carbureter, a pressure of 1 pound per square inch being ample when an engine-driven air pump is fitted.

In some very old models of cars fitted with pressure tank the pressure of the gases exhausting from the engine has been utilized, by connecting a pipe, having a check-valve opening toward the tank, to the exhaust pipe and the top of the tank. A hand air pump was used for pumping the initial pressure for starting. This method of pressure feed is here mentioned because a few of these old cars are still in service.

When an engine-driven air pump is used, either a separate pressure-relief valve or one incorporated with the air pump must be used, to prevent pumping an excessive pressure, or the same object can be accomplished by making the pump compression space adjustable. A pressure gauge is a necessity with any pressure-feed system; the pressure normally carried ranges from 2 to 4 pounds per square inch.

While pressure fuel feed was at one time quite extensively used, it is at present employed in only a few cars, usually when lack of available space prevents the installation of a vacuum-feed system.

34. A few of the older cars have made use of a combined pressure and gravity-feed fuel system. A small auxiliary fuel

tank, called the *service tank,* is placed on the dashboard under the cowl. From this tank, which is fitted with a gauge that is placed on the cowl board and shows the quantity of fuel in the service tank, the fuel flows by gravity to the carbureter. The main supply tank is carried in the rear and at a lower level than the service tank. When the service-tank fuel gauge shows this tank to be nearly empty and there is no pressure on the main tank, a little air pressure is pumped up on the main fuel tank by means of a hand air pump mounted on the cowl board, thus forcing fuel from the main tank to the service tank. When running the engine, the proper air pressure is maintained on the main tank by means of a small single-acting air pump incorporated with the engine. The service tank is fitted on its inside with a float that falls as the fuel level falls, and in doing so opens a valve at the end of the fuel pipe coming from the main fuel tank, thereby admitting fuel. As the fuel level rises the float rises, and in so doing closes the valve that controls the inflow of the fuel.

RESERVE FUEL SUPPLY

35. A reserve compartment is provided in several makes of fuel tanks. This compartment has a capacity of a gallon or more, and is so arranged that the fuel will not flow out until a valve, which is ordinarily kept closed, is opened. Thus, after all the fuel is used from the main part of the tank, there is still a reserve of a definite quantity, which is generally sufficient to carry the car to some source of supply. It is advisable to have this reserve tank so located that, when putting in a fresh supply of fuel, the fuel will first enter the reserve tank and then overflow into the main compartment. In this way the fuel in reserve is always fresh. While a reserve compartment in the fuel tank was very popular at one time, it is today but seldom used.

VACUUM-FEED FUEL SUPPLY

36. While pressure-feed gasoline systems have proved very reliable, yet they are subject to minor derangements, such as failure of the pump check-valve to seat properly, leaky joints

in the several pipe lines, leaky joint at the gasoline-tank cap or at the gasoline gauge, a carbureter that floods persistently if the air pressure is too high, etc. Another objection to pressure feed is the necessity of pumping up pressure by hand after the car has been standing idle for a few hours, and every time the gasoline tank has been filled. All annoyances incidental to pressure feed from a tank at the rear end below the carbureter level are eliminated by the vacuum-feed fuel system, which is now regularly fitted to many makes of cars, and can be applied to most old cars with a tank below the carbureter level. Briefly, the vacuum-feed fuel system consists of means by which fuel from the fuel supply tank is forced by the pressure of the atmosphere into a small supplementary tank above the carbureter level and near the carbureter, whence the fuel flows to the carbureter by gravity.

The vacuum-feed fuel system is not applicable to gravity fuel tanks in the cowl, but can advantageously be applied to gravity fuel tanks under the front seat in order to permit raising the carbureter so as to bring it as close to the engine cylinders as possible and into a warmer place. Much better vaporization of the fuel, and less condensation in the intake manifold, is secured by raising the carbureter, and consequently the gasoline economy is improved.

37. The vacuum fuel-feed system in common use employs the *Stewart vacuum tank*. The present model of this tank is shown in Fig. 5 (*a*), and the model first placed on the market in view (*b*), both being shown in cross-section. The operation of both models is identical, their only difference being in constructional details; the same parts are lettered the same, and hence the views of both models can be referred to in reading the description.

The vacuum tank *a* is cylindrical in form and is divided into two chambers. The lower chamber *b* forms a receptacle for gasoline, and is connected by a pipe *c* to the gasoline inlet of the carbureter; this pipe *c* extends some distance above the bottom of the chamber *b*, and consequently the lower part of *b* serves as a settling chamber for water or other impurities in

the fuel. By removing a plug *d*, or opening a drain cock screwed in its place, the chamber *b* can be drained, or a small gasoline supply obtained for priming the engine cylinders, etc.

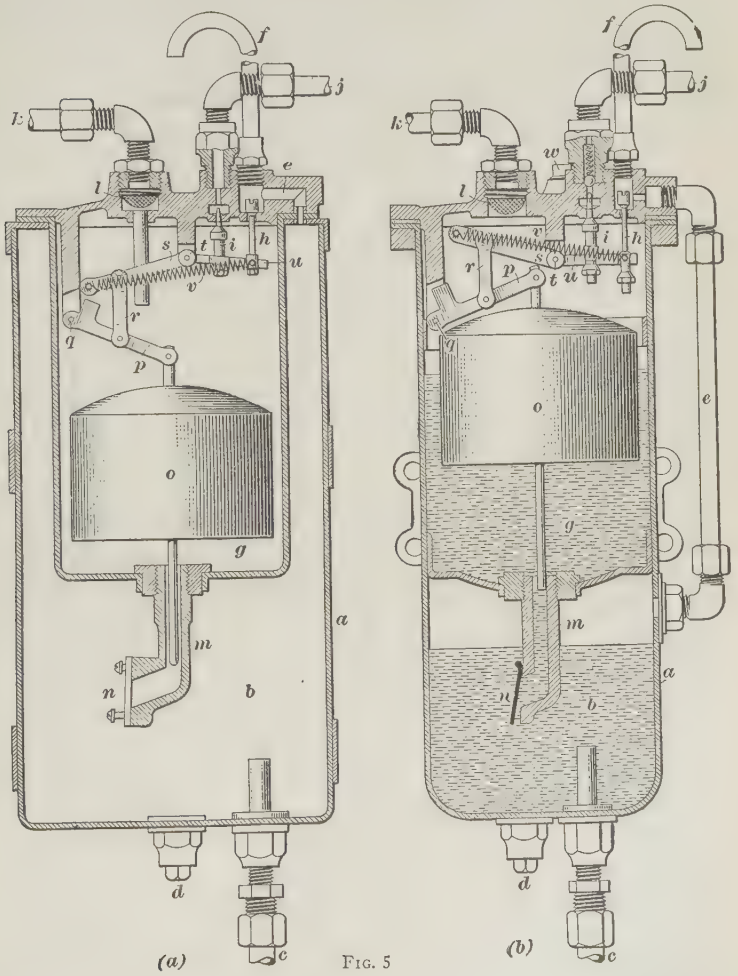

FIG. 5

The lower chamber *b* at all times is open to the atmosphere by way of the passage *e* and vent pipe *f*. The upper chamber *g*, while the engine is in operation, is alternately open to the atmosphere through the atmospheric valve *h*, and to the intake

manifold of the engine by the vacuum valve *i*; in the latter case, a partial vacuum exists in the upper part of the chamber *g*. A pipe connection *j* leads from the vacuum valve *i* to the intake manifold, and another pipe connection *k* leads to the gasoline supply tank; a removable brass-wire gauze strainer *l* is placed at the gasoline inlet to the upper chamber. The lower chamber *b* and the upper chamber *g* are connected by an elbow *m* having a flap valve *n* at its lower end. The upper chamber *g* contains the hollow metallic float *o*, which is connected to the lever *p* having its fulcrum at *q*. The lever *p* is attached by the connecting link *r* to the lever *s* having its fulcrum at *t*; the lever *u*, which also has its fulcrum at *t*, has the atmospheric valve *h* and vacuum valve *i* attached to it. The two levers *s* and *u* are free to swing on their common fulcrum *t* independently of each other; their free ends are connected together by the helical tension spring *v*, known from its method of attachment as an *over-center spring*, as in operation it moves from one side of the center of the fulcrum *t* to the other.

38. The operation of the Stewart vacuum tank is as follows: With the tank entirely empty, as is the case when the device has just been applied to a car or all fuel drained from the tank, the float *o* has fallen to the position shown in Fig. 5 (*a*), where the atmospheric valve *h* is closed and the vacuum valve *i* is open. If the engine is now cranked, either by means of the self-starter or by hand, and the throttle is closed, a partial vacuum is created in the intake manifold and hence also in the upper chamber *g*, the flap valve *n* being closed. Consequently, the pressure of the atmosphere on the fuel in the main supply tank forces fuel into the upper chamber *g* through the pipe *k*. The float *o* is thereby raised, and also the levers *p* and *s*, the lever *u* being at rest, until the continued rising of the float brings the over-center spring *v* to the upper side of the fulcrum *t*, which position is shown in (*b*), when this spring suddenly pulls up the lever *u*, thereby closing the vacuum valve *i* and opening the atmospheric valve *h*. Air then fills the upper part of the upper chamber and gasoline flows by gravity past the flap valve *n* into the lower chamber and to

the carbureter. The float now falls and as soon as it has fallen far enough to bring the over-center spring *v* to the lower side of the fulcrum *t*, this spring suddenly pulls the lever *u* down, thereby closing the atmospheric valve *h* and opening the vacuum valve *i*. Fuel now flows from the main supply tank into the upper chamber again, raises the float and finally closes the vacuum valve and opens the atmospheric valve again. The upper chamber thus alternately partly empties itself into the lower chamber and is filled again.

39. The vacuum-feed tank is usually placed on the engine side of the dash board; if conditions permit it to be readily placed nearer the carbureter, this should be done. The bottom of the tank should be at least 3 inches above the fuel level of the carbureter, and as much higher as circumstances permit. It is necessary that the top of the vacuum-feed tank be above the top of the main fuel supply tank, so that there is no danger of gasoline flowing into the vacuum-feed tank by gravity when descending steep hills and overflowing through the vent pipe *f*, Fig. 5. The use of a vent pipe extending higher is equivalent to raising the vacuum-feed tank.

Should the vacuum-feed tank, when empty, refuse to fill when the engine is cranked rapidly with the throttle closed, the probability is that some dirt has accumulated on the seat of the flap valve *n*. A pipe plug in the head of the tank, which plug can be seen at *w*, Fig. 5 (*b*), should then be removed and gasoline poured in through a small funnel; this gasoline will usually wash all dirt from the seat of the flap valve and the tank will operate properly again as soon as the pipe plug is replaced. If this treatment fails to effect a cure, the tank must be taken apart and the flap valve cleaned. It is necessary that the joint between the body and head of the tank be air-tight; a gasket shellacked on both sides is used to pack the joint.

If gasoline is drawn from the tank through the pipe *j* into the intake manifold, which manifests itself through the choking and stopping of the engine, it shows that the float has sprung a leak and consequently cannot operate. The remedy is to remove the gasoline from the float and then repair it or replace it.

MEASURING THE FUEL SUPPLY

40. The simplest, but by no means the most convenient, way of determining the quantity of fuel contained in a fuel tank is to insert a straight stick or a wire through the filling hole until the end touches the bottom of the tank and then quickly withdraw it and note how far from the bottom it is wetted by the fuel. This indicates the depth of fuel in the tank, but does not tell directly the amount of fuel.

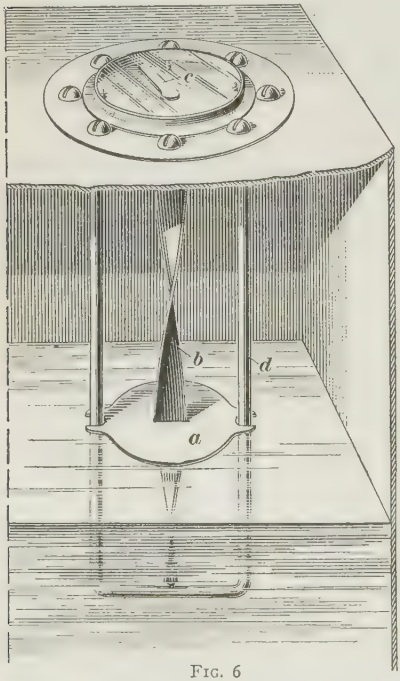

FIG. 6

To determine the quantity of fuel in the tank, a graduated *fuel gauging stick* must be used. Such a stick is easily made in the following manner: Commencing with an empty fuel tank, pour in a half gallon or a gallon of the fuel at a time and then mark the height each measureful produces in the tank on a clean wooden stick. After the fuel gauging stick has been marked, it may be varnished with shellac varnish, which is not attacked by any fuels derived from crude oil.

41. The most convenient way of ascertaining the quantity of fuel in the fuel tank is to use a *fuel gauge* fitted to it; in modern practice this is usually fitted to the tank itself, irrespective of whether it is under the cowl or in the rear.

Most modern fuel gauges depend upon the action of a well-shellacked cork or hollow metallic float that floats on the surface of the fuel and rises and falls with it, the position of the

cork or float, and hence the height of fuel in the tank, being indicated by a pointer moving over a graduated dial. As a general rule, the fuel-gauge dial is not graduated to read to gallons, but it reads from *Empty* to *Full,* by eighths, quarters, and halves.

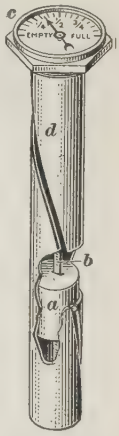

FIG. 7

As gasoline is the common fuel, fuel gauges are commonly referred to as *gasoline gauges;* some of these are applicable to pressure tanks as well as to non-pressure tanks such as are used with a vacuum-feed system. A gasoline gauge for a pressure-feed tank must have its indicating mechanism, which is outside of the tank, sealed against the escape of the air inside the tank.

42. One form of fuel gauge operated by a float is shown in Fig. 6. In this gauge, the float *a* is made of cork; a slot in the center of the float engages with a twisted flat stem *b*. As the float rises or falls, this stem is moved around and carries with it a hand, or pointer, *c,* which moves over a dial graduated to indicate the quantity of fuel in the tank. Rotary motion of the float *a* is prevented by the frame *d,* with which lugs at the edge of the float engage.

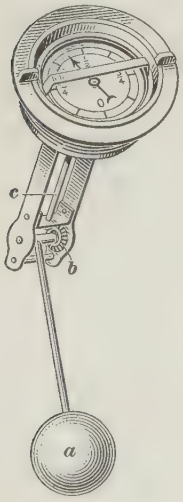

FIG. 8

A common modification of the gasoline gauge shown in Fig. 6 has a brass tube surrounding the cork float; a straight vertical slot is cut into the brass tube, and a pin driven into the float fits into this slot and prevents rotation of the float.

43. The gasoline gauge shown in Fig. 7, like that in Fig. 6, is intended chiefly for rear tanks. In this case the float *a* moves on and rotates a flat strip *b* to one end of which a pointer is fastened, which moves over a graduated dial *c* to indicate the quantity of fuel in the tank. The float is rotated by means of a pin fastened to it that engages a helical slot in the tube *d*. The dial *c* is sometimes graduated to show gallons.

44. The forms of gasoline gauges explained in Arts. **42** and **43** are intended for vertical installation, and therefore are illy adapted to cowl tanks having their filler opening on the cowl board. For such installations, in which it is desirable to have the gasoline-gauge dial nearly vertical, a form of gauge like that shown in Fig. 8 is often used. In this gauge the hollow metallic float *a* operates a bevel gear *b* meshing with another bevel gear on the shaft *c*, this shaft on its outer end carrying a pointer moving over a graduated dial.

45. Cork floats of gasoline gauges, if not thoroughly shellacked, are liable to become gasoline soaked, in which case they will show much less gasoline than there is in the tank. Likewise, hollow metallic floats, owing to defective workmanship, may fill up with gasoline. The remedy in the first case is to dry out the cork float (this may take several days in a warm place) and then to dip it into shellac and allow it to dry thoroughly before reassembling the gauge. In the second case the remedy is to empty the metal float by placing it in a warm place, and when entirely empty to resolder the defective joint.

FUEL-TANK ACCESSORIES

46. If the fuel is drawn directly from the bottom of the fuel tank, any sediment or water that may be in the tank is liable to pass into the pipe leading to the carbureter, and thus cause trouble. To prevent this, practically all gravity fuel tanks are provided with a *sediment bowl* or *sediment chamber*, which is a small chamber extending downwards from the lowest point of the tank and forming a part thereof. The pipe leading to the carbureter enters the side of the sediment bowl a slight distance, say about 1 inch, above its bottom; the space below the point where the pipe enters forms a catch basin in which sediment and water can lodge. The bottom of the sediment bowl is usually fitted with a drain plug; upon removal of this plug foreign matter may pass out, or some of the fuel may be drawn from the tank if desired.

In pressure-feed and vacuum-feed tanks, the fuel pipe generally enters through the top of the tank and extends down-

wards to within about $\frac{1}{4}$ inch of the bottom; hence, there is little danger of impurities lying on the bottom of the tank passing into the fuel pipe. Pressure-feed and vacuum-feed tanks also are often fitted with a sediment bowl, from which any dirt or water that collects may be drawn off.

47. Pressure-feed tanks are always fitted with an air-pressure gauge, which is usually placed on the cowl board so as to be in plain sight of the driver. This gauge may be connected directly into the pipe line conveying air under pressure to the tank from the hand air pump and engine-driven air pump, as shown in Fig. 4, or it may be connected to the tank by an independent pipe line. Both methods of installation are in use, and both have proved satisfactory.

48. The larger sizes of fuel tanks are usually fitted with vertical flat **splash plates,** which divide the fuel tank into several compartments that communicate with each other through relatively small openings at the top and the bottom of the splash plates. These plates prevent the whole body of fuel contained in the tank from being suddenly thrown from one side to the other when the car changes its direction, or, on account of the contour of the road, is tipped sidewise, thereby preventing unnecessary strains on the fuel tank and a disagreeable swishing noise that would manifest itself otherwise. Incidentally, splash plates serve to stiffen the tank to which they are applied.

49. A removable **strainer** is often fitted to the filler opening of fuel tanks. This device is usually made in the form of an inverted cone and of fine-mesh brass or copper wire gauze. The purpose of the strainer is to prevent dirt from entering the tank when filling it. If the filler opening has no strainer fitted to it, the funnel through which the fuel is poured into the tank should have one.

While a strainer will keep dirt out of the tank, it will not keep out water that sometimes finds its way into the liquid fuel. For this reason a fuel strainer is occasionally placed in the pipe line between the fuel tank and the carbureter. This fuel strainer is a vessel in which any water in the fuel can

settle to the bottom and be removed through a drain cock; a fine-mesh wire gauze prevents dirt passing to the carbureter.

While a fuel strainer placed in the pipe line between the fuel tank and the carbureter is of undoubted benefit, its use has declined, because many modern carbureters have such a strainer incorporated in their construction. Also, when vacuum feed is used, the vacuum tank is fitted with both a strainer and a settling chamber.

50. A shut-off cock or valve is usually fitted somewhere between the fuel tank and the carbureter; in case of pressure-feed and gravity-feed tanks the shut-off cock is a necessity, to prevent serious loss of fuel when it becomes necessary to disconnect the carbureter for examination and repair. In case of vacuum feed a shut-off cock between the vacuum tank and carbureter is desirable, but is often omitted because the loss of fuel is not very serious when the carbureter is disconnected, being limited to the fuel contained in the lower chamber of the vacuum tank, which rarely exceeds 1 pint at the most.

51. Some method of draining a fuel tank is very desirable. With rear tanks of the better grade of cars a drain plug, which is usually a pipe plug ranging in size from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch, is commonly fitted to the sediment bowl. Cowl tanks and gravity tanks under the front seat are sometimes fitted with drain cocks, but more often the shut-off cock also serves to drain the tank; it is necessary to disconnect the feed pipe for this purpose.

PRINCIPLES OF CARBURATION

PRINCIPLES OF CARBURETERS

INTRODUCTION

52. A *carbureter* is an appliance for atomizing and vaporizing a liquid hydrocarbon fuel, which is gasoline in automobile work, and mixing it with air in proper proportions to form a combustible mixture at all engine speeds.

By *atomizing* is meant changing the liquid fuel mechanically into a very finely divided spray; by *vaporizing* is meant the changing of the spray into a vapor or gas. Both processes take place simultaneously in a carbureter, the one first named being accomplished by having the liquid fuel issue from a small orifice at fairly high speed into an air current moving at high speed, and the second process involving the application of heat.

53. A successful automobile carbureter must fulfil the following requirements:

1. It must give a practically uniform mixture, whether the demand on it is light or heavy, within the range of the speed actually attained by the engine. The mixture must be properly proportioned when the engine is running slowly with the throttle wide open, as when going up a hill, or slowly with the throttle nearly closed, as when coasting or traveling slowly on the level, or when running at the highest speed with the throttle wide open.

2. It must not be unduly sensitive to changes in the quality of the fuel, and it must admit of easy adjustment for such ordinary variations in density as are likely to be encountered. This does not necessarily mean, however, that the adjustment should be under the control of the operator, as some very

successful carbureters are purposely made without adjustment means, the carbureter being correctly set at the factory.

3. It must not be unduly sensitive to changes in the level of the car, as when climbing or descending a hill, or when turning off the road into the gutter.

4. It must atomize the fuel reasonably well when starting in cold weather.

5. It must operate equally well whether the engine has two cylinders giving intermittent suction or a larger number of cylinders giving practically a continuous suction.

6. The quality of the mixture delivered must not be affected by the vibration of the car.

7. The carbureter must not be exposed more than necessary to the entrance of dirt, and all parts to which dirt is likely to find its way must be readily accessible for cleaning.

8. It should be provided with proper means not only to atomize the fuel, but to vaporize the heavier constituents which do not vaporize at ordinary atmospheric temperatures.

In regard to requirement 8, it may be stated that with the present-day gasoline no carbureter fully meets this; a compromise is effected in good practice by further heating of the combustible charge after it leaves the carbureter, and even with this heating, complete vaporization of the fuel is not attained. This statement refers distinctly to the automobile gasoline of commerce rather than to high-grade fuel not obtainable ordinarily except on special order.

CARBURETER NOMENCLATURE

54. While the many carbureters on the market or made by automobile manufacturers for their own cars differ very much in appearance, most of them embody certain features common to all. In order to illustrate these features, a model G L Rayfield carbureter is shown in cross-section in Fig. 9 (*a*) and in perspective in (*b*). Both views, as far as possible, are lettered alike, and both should be referred to in reading the description.

The carbureter consists of a *float chamber a* containing a *float b* that is lighter than the fuel delivered from the fuel tank

through the *fuel-inlet union connection c.* This float *b,* rising and falling with the fuel level in the float chamber *a,* maintains

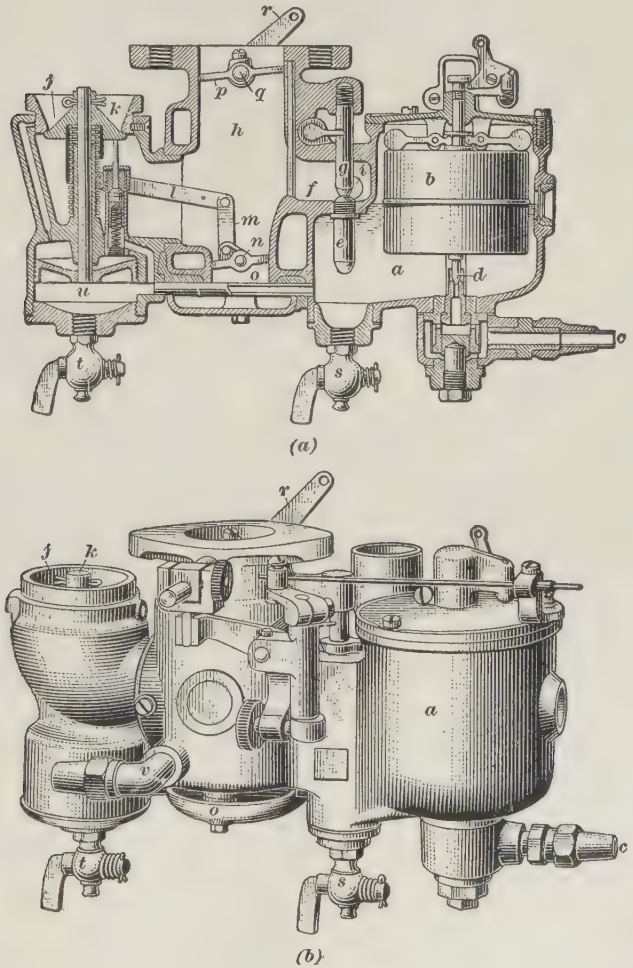

Fig. 9

a practically constant fuel level by operating the *fuel needle valve d,* which alternately opens and closes the fuel inlet to the float chamber. The fuel flows from the float chamber to the

spray nozzle, or *fuel jet, e,* which opens in this case into a chamber *f* and whose area of opening, which determines the amount of gasoline passing from the nozzle, is controlled by the *needle valve g.* The gasoline coming from the spray nozzle *e* passes into the *mixing chamber h,* where at low engine speeds it mixes with air entering through the air inlet *i.* This particular make of carbureter has two *auxiliary air inlets* that open for the admission of air to an extent depending directly upon the vacuum formed. The one air inlet *j* is closed at low speeds by the spring-loaded *auxiliary air valve k;* an arm *l* is rigidly fastened to the air valve *k* and connected by a link *m* to the butterfly valve *n* controlling the second auxiliary air inlet *o.* The quantity of mixture passing to the engine cylinders is controlled by the *butterfly throttle valve p,* which is a circular disk fastened to the rotatable *throttle-valve stem q* that carries the *throttle crank arm r,* which, in turn, is connected to the accelerator pedal and hand throttle lever.

The throttle valve of a carbureter for an automobile engine is always so arranged that when properly adjusted it is impossible to stop the engine by closing the throttle, but merely to slow it down to the lowest speed at which it will still keep in motion, which is called the *idling speed* of the engine. This is very necessary in order to retain control of the car when it is driven very slowly, which control would be lost were closing the throttle to stop the engine. On all carbureters for automobile use, the degree of opening of the throttle valve for the idling speed of the engine is adjustable by means of a set screw called the *throttle stop screw;* this is usually carried by the throttle crank arm, and after adjustment can be locked in position. In a few carbureters a second stop screw is provided for limiting the maximum opening of the throttle.

55. Many carbureters are provided with a drain cock for the float chamber, as shown at *s* in Fig. 9. The particular model of carbureter illustrated in Fig. 9 is fitted with a second drain cock *t* for draining gasoline from the chamber *u.* This carbureter is also provided with a hot-water jacket for the mixing chamber, hot water from the cooling system of the

engine entering at v and leaving through a similar connection at the opposite side of the carbureter, which therefore cannot be seen in the views given. In modern practice few water-jacketed carbureters are used as regular equipment on cars, partly on account of their extra cost, partly because the gain in economy by water-jacketing is very slight with the present-day gasoline, and partly because in practice greater economy of fuel is obtainable by bringing the fresh charge into contact with highly heated surfaces after it leaves the carbureter.

PRINCIPLES OF SPRAY CARBURETERS

56. The spray carbureter has one or more nozzles or jets with one or more small, almost minute, openings, or orifices. For convenience of discussion, it will be assumed at first that one nozzle is used and that the nozzle has only one orifice.

The engine piston, on its suction stroke in the cylinder, creates a partial vacuum at the orifice of the nozzle, and hence gasoline coming from the float chamber is forced out of the nozzle by the pressure of the air; this is commonly spoken of as the engine drawing gasoline from the nozzle. The gasoline emerges from the nozzle in the form of a more or less finely divided spray, a large part of which vaporizes on coming in contact with air rushing at a fairly high velocity past the nozzle. It is the purpose of the carbureter to combine the gasoline vapor, gasoline spray, and air in such proportions under all conditions as to form a combustible mixture.

In practically all carbureters, while the engine is at rest, the spraying orifice of the nozzle is from $\frac{1}{8}$ to $\frac{3}{16}$ inch above the level of the body of the fuel to which it connects. When the engine is running, the level of the fuel may be as much as $\frac{3}{8}$ inch or more below the spraying orifice of the nozzle.

57. Some of the elements of a spray carbureter are shown connected to an engine in Fig. 10, which assumes the engine is viewed from the driver's seat. At a is shown the fuel reservoir and at b the nozzle, which has an orifice that opens vertically upwards in this particular case and is connected to the fuel in the reservoir a by the passage c. This passage is

considerably larger in sectional area than the orifice. The spray nozzle *b* is inside the air admission tube *d* having the air inlet *e* at the bottom in this case. The mixed air and gasoline passes the throttle valve *f* and open inlet valve *g* into the cylinder *h* during the suction stroke of the piston *i*, as indicated by the arrows.

In actual carbureters the gasoline nozzle *b* is not always in line with the air tube *d*, as in Fig. 10; in some carbureters it is

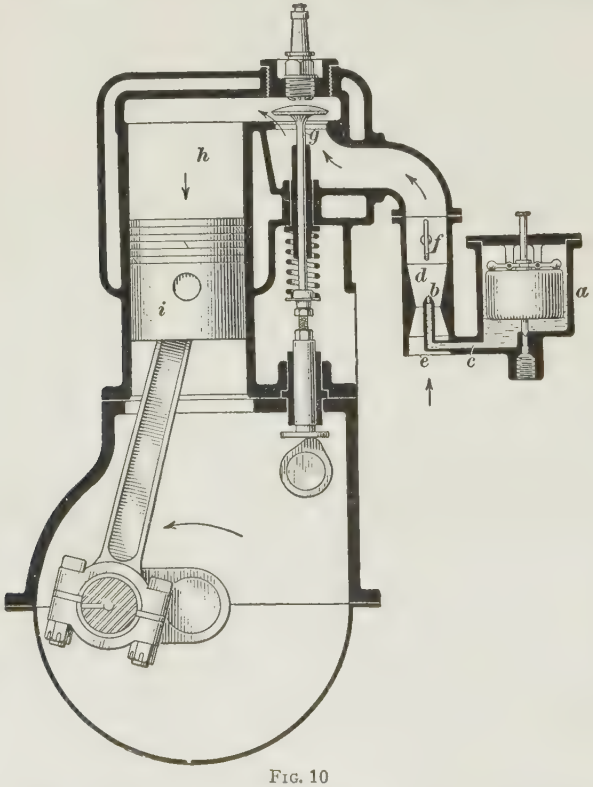

Fig. 10

at an angle to the air tube, although the nozzle opening is usually slightly beyond the narrowest part of the tube. In some carbureters the air tube does not have the form shown in Fig. 10 but is of the same diameter throughout its length; neither is the air tube necessarily straight, but it may be curved.

58. The form of air tube employed in Fig. 10 is known as the *Venturi tube;* as clearly shown in the sectional view of such a tube presented in Fig. 11, this consists of two tapering pipes joined at their small ends so as to form a continuous tube. A fluid entering at *a,* and flowing in the direction of the arrow, passes first through a rapidly narrowing part until it reaches the narrowest cross-section at *b,* known as the *throat,* and then passes through a gradually widening part to the discharge orifice at *c.* This form of tube derives its name from the Italian physicist Venturi, who experimented with various modifications of it and discovered certain peculiar facts with reference to its influence on the rate of flow and the quantity of discharge of fluids passing through it.

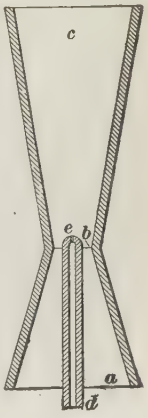

FIG. 11

59. When a fluid under constant pressure flows through a short tube of uniform diameter, the velocity of flow is practically the same at all points; but when the flow occurs in a Venturi tube, the velocity varies, being least at the cross-section of greatest area and greatest at the cross-section of least area. The quantity of the fluid discharged from the Venturi tube is greater than that from a straight tube having a uniform diameter equal to the diameter of the Venturi tube at its throat. The ratio of the discharge from the Venturi tube to the discharge from the straight tube may be 2 to 1, or even greater, depending largely on the lengths of the tapering parts and the inclination of their sides.

60. The reason for the greater velocity and discharge from a Venturi tube than from a straight tube lies in the fact that a partial vacuum is formed in the Venturi tube at a point just beyond the throat. For example, in Fig. 11, the flow of fluid through the tube in the direction from *a* to *c* results in the formation of a partial vacuum at the throat *b,* and if a small pipe were attached at this point, air would be drawn into the Venturi tube through it to destroy the vacuum produced. In the case of a straight tube, no vacuum is formed and the flow

is not so rapid, inasmuch as the pressure is practically constant at all points along the tube. In the Venturi tube, the formation of the partial vacuum beyond the throat causes less resistance to the flow, and because of this decreased resistance the velocity of flow and the discharge are greater.

61. It has been explained that the use of a Venturi tube enables an increased flow to be obtained and at the same time produces a partial vacuum at the narrowest part of the tube, which in an actual carbureter increases the partial vacuum created by the pistons on their suction strokes. These principles are made use of in most designs of carbureters to insure good atomization of the gasoline and thorough mixing with the air. The method of applying a Venturi tube to a carbureter was shown in Fig. 10, where it was explained that the air supply enters at *c* and after passing the throat passes into the upper diverging passage and then into the chamber containing the throttle valve *f*, which chamber is often referred to as the *carbureter mixing chamber*. The gasoline is supplied through the spray nozzle *b*, which is inserted in the lower end of the Venturi tube and is of such length that the nozzle orifice is central in the tube at a point just beyond the throat. In other words, the upper end of the nozzle *b* is located at the point where the pressure is least, so that, when the carbureter is working, the gasoline is discharged from the nozzle orifice into a partial vacuum, thus insuring a greater flow.

62. The formation of a partial vacuum at the throat of the Venturi tube simply indicates that the pressure at that point is reduced until it is less than the pressure of the external atmosphere. The gasoline in the float chamber to which the gasoline nozzle is connected is acted on by atmospheric pressure, or about 15 pounds per square inch at sea level; whereas, the gasoline issuing from the nozzle orifice is subjected to a pressure that may be less by several pounds per square inch. As a result of this unbalanced condition of pressures, the gasoline is forced rapidly through the gasoline nozzle and is discharged from the nozzle orifice in the form of spray, which is caught up by the air supply and carried on toward the mixing cham-

ber. The reduction of pressure at the end of the gasoline nozzle also insures a more rapid vaporization of the gasoline. It is a well-known fact that the temperature at which a liquid boils and changes into vapor is lowered by reducing the pressure on the liquid. Thus, water will boil at a temperature of 212° F. at sea level; but at the top of a mountain 1 mile above sea level, where the pressure is less because the air is rarer, water will boil at 202° F. Similarly, when the gasoline is discharged into the Venturi-tube throat, where the pressure is reduced, its boiling point is lowered considerably and the result is that it flashes into vapor much more readily than when subjected to atmospheric pressure.

63. The flow of gasoline from a plain carbureter spray nozzle, that is, a spray nozzle consisting simply of a passage for the fuel and a spraying orifice, does not increase or decrease in direct proportion to the increase or decrease in the flow of air through the air tube past the spray nozzle. It is a fundamental law of nature that as the vacuum of a plain spray nozzle increases, due to greater engine speed or throttle openings, the flow of gasoline increases more rapidly than the flow of air; consequently, to obtain the desired mixture, it is necessary either to reduce the vacuum, by permitting additional air to enter between the nozzle and the engine, or else to alter the rate of flow of the gasoline by some other suitable means. As automobile engines have to run at greatly varying rates of speed, the law of nature stated prevents the use of a simple mixing valve such as works very satisfactorily on stationary and other engines run at a constant speed, as such a mixing valve can be adjusted to give a substantially correct mixture over only a rather small speed range. This fact calls for the employment of an *automatic carbureter,* the chief function of which is to furnish a substantially correct mixture over a very large range of engine speed, which in practice may be between the limits of 100 and 3,600 revolutions per minute of the crankshaft.

Since there is a limit to the degree of vacuum that can be produced at a carbureter nozzle, it follows that there is also a

maximum limit to the quantity of gasoline that can pass a given-sized orifice in the spray nozzle. Therefore, in constructing carbureters the designer has the choice of using a single nozzle large enough to supply all the gasoline needed at extreme powers of the engine, or to use two or more spray nozzles that necessarily come into action and supplement one another; both constructions are used in practice and work satisfactorily.

CARBURATION SYSTEM HEAT SUPPLY

64. Heat is required for the vaporization of any liquid. In the case of the present-day commercial gasoline sold regularly for automobile and truck use, the boiling point of only a small part of the gasoline is low enough to cause this to vaporize at ordinary atmospheric temperatures, even in midsummer; the greater part of such gasoline has a high boiling point, ranging as high as 450° F. in the case of the heaviest constituents. Therefore, in order to insure proper vaporization as well as atomization of the gasoline, and thereby promote economy in the use of fuel, it is necessary to apply heat to the gasoline, usually after atomization.

When gasoline having a fairly low temperature of vaporization of the major parts of its constituents was available everywhere, good results were obtained by preheating the air supply to the carbureter, water-jacketing the carbureter mixing chamber, and water-jacketing the inlet manifold, and circulating the cooling water through these water-jackets. The maximum temperature in such water-jackets rarely exceeds 170° F., which temperature is entirely too low to vaporize a large part of the present-day gasoline, however, although it is a decided improvement over the absence of any heat supply.

65. The application of heat to the liquid gasoline aids the vaporization of the lighter constituents, and thereby promotes economy in the use of fuel; in practice this method is applied to vacuum-feed tanks by placing such tanks as close to the cylinders and carbureters as possible, in order that the heat radiated from the cylinders may warm the liquid gasoline in

the vacuum tank. Attempts have been made to heat the gasoline in the float chamber of the carbureter by a heating coil heated by the passage of an electric current taken from the storage battery of the car. Such attempts have proved successful in facilitating the starting of a cold engine; but, such heating devices are useful only for the purpose stated, because their large current consumption will quickly drain the storage battery.

66. The standard method, in modern high-grade automobile practice, of obtaining satisfactory vaporization of the gasoline is to apply heat to the mixture of gasoline and air by bringing the mixture into direct contact with exhaust-heated surfaces before it passes into the cylinders of the engine. Naturally the vaporization of the gasoline is aided by preheating the air supply by passing it at a low velocity over an exhaust-heated surface, which in practice is the exterior of the exhaust manifold. In one method the carbureter mixing chamber is heat-jacketed and part of the hot exhaust gases are circulated through this jacket. While this method is a great improvement over a carbureter water-jacket, owing to the higher temperature that obtains, for best results in vaporization it needs supplementing by using an exhaust-jacketed manifold, a hot-spot system of manifolding, or a combined intake and exhaust manifold. In fact, one or the other kind of heated manifold is virtually a necessity today with any carbureter if economy in the use of the ordinary commercial gasoline is desired. The foregoing statement does not imply by any means that every modern car is fitted with an entirely satisfactory appliance for heating the mixture; many cars are still built and sold in which rather indifferent heating provision is made, or in which heating is limited to a preheating of the air.

67. There are many of the older cars in operation, with carburation systems that were very satisfactory when the car was built and on the grades of gasoline then obtainable, in which the gasoline economy and the operation of the engine, especially before the latter is fully heated, has become very

unsatisfactory to their owners or drivers. In many such cars the carburation system can be modernized at small expense either by fitting a combined intake and exhaust manifold, if one to fit the engine can be obtained in the market, or by exhaust-jacketing the intake manifold. In some cases a great improvement is noted after just fitting some suitable arrangement for preheating the air supply to the carbureter. No general rule can be laid down for modernizing the carburation system of an old car; each individual case must be treated on its own merits and in accordance with circumstances.

As a general rule, little can be done to modernize the carburation system of engines not having an external intake manifold, beyond fitting means of preheating the air supply if none such are provided, or using a water-jacketed or exhaust-heat-jacketed carbureter if conditions permit its ready installation.

68. As heating either the air or the mixture, or both, causes them to expand and therefore to become lighter, less weight of fresh charge is taken into the engine at each suction stroke for a given throttle opening and engine speed than if the air and mixture were cold; this, in theory, reduces the maximum pressure on the pistons during the explosion strokes. However, the actual explosion pressures obtainable in practice with a heated mixture differ so slightly from those gotten from an unheated mixture that this theoretical objection is of no practical importance in general, excepting for special work, such as racing. Furthermore, with an unheated mixture, not only is the gasoline economy extremely low, but the working of the engine, excepting perhaps in hot summer weather, is very unsatisfactory.

Theoretically, the heat supply to the carbureter and mixture should be susceptible to regulation to suit climatic conditions; as a matter of fact, however, all the heat available in practice in the hottest summer weather is scarcely sufficient for proper vaporization of all the gasoline constituents, and consequently means of regulating the heat supply, while often fitted, are of doubtful value. This explanation refers distinctly to the use of commercial gasoline as regularly sold for automobile, truck,

and tractor use; with high-grade special gasoline having a very low boiling point of its heaviest constituents, which is not ordinarily available at present, heat regulation was a necessity.

69. The principle involved in heating the carbureter air supply is shown in Fig. 12, the device illustrated not being of any particular make. Around the exhaust pipe is fitted a cast- or sheet-metal sleeve *b*, usually referred to as a *carbureter stove*, the inside diameter of which is somewhat greater than the outside diameter of the exhaust pipe. The stove is held away from the pipe all around by the lugs *c*, and thus a space is formed inside the sleeve, surrounding the exhaust pipe. One end of the pipe *d* is attached to the sleeve and the other end is joined to the main air intake of the carbureter. Under the effect of the suction in the carbureter, air is drawn in between

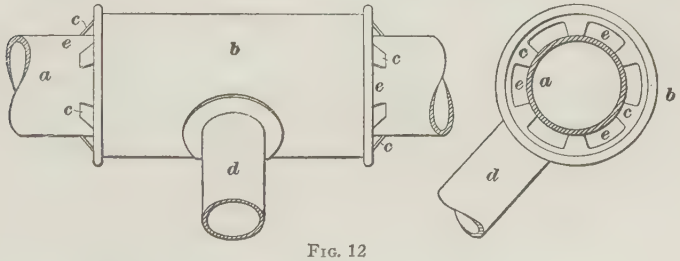

FIG. 12

the sleeve and the exhaust pipe through the openings *e*, and is heated by direct contact with the hot exhaust pipe. It then flows through the pipe *d* to the carbureter, where the heat that it has absorbed is utilized in producing more thorough vaporization of the gasoline spray.

In some cases the stove for preheating the air is not a separate unit, but is cast in one with the exhaust manifold. The pipe conveying the heated air to the carbureter is usually a piece of flexible steel tubing made especially for this purpose.

70. A means for regulating the heat to which the air is preheated is still often found on both new and old cars, although there is but little if any need for its use; this consists of an adjustable shutter by which cold air and heated air can be mixed in suitable proportions.

For regulating the heat supply to exhaust-heat jackets, the simplest and most commonly used device is a butterfly valve the position of which in the pipe connecting the exhaust pipe to the jacket can be changed by hand; but, as stated in Art. **68,** the utility of this regulation is of doubtful value in practice. Combined intake and exhaust manifolds, as well as hot-spot manifold systems, have no means of regulating the heat supply to the intake.

PRINCIPLES OF CARBURETER CONSTRUCTION

FLOAT-FEED SPRAY CARBURETERS

71. The universally adopted method of maintaining a nearly constant level of fuel in the reservoir of the carbureter is by means of a float to which is attached a valve that cuts off the inflow of fuel from the supply tank when the liquid rises to a predetermined level. The float is, of course, placed in the fuel contained in the carbureter reservoir. The device is called a *float feed*. The float is adjusted to maintain a fuel level slightly lower than the top of the nozzle. This is done in order to secure a margin of safety to allow for inaccurate operation of the float and valve, so that there will not be excessive flow of fuel from the nozzle in case the float allows the liquid to rise slightly above its normal level; also, to prevent dripping when the car is idle, and overflow due to the tipping of the carbureter when the car is out of level, as on a hill or the side of a crowned roadway, or on account of vibration.

It should be clearly understood, however, that dripping of gasoline from the bottom of the carbureter when the engine is idling, or for a little while after the engine has been stopped, is not necessarily an evidence in every case of a defective carbureter. As a matter of fact, the present gasoline of commerce has heavy constituents that do not vaporize even in exhaust-jacketed manifolds. These constituents at the higher engine speeds are swept by the high velocity of the mixture into the engine cylinders, but when the engine is idling, they

collect on the intake manifold walls and run down to the carbureter by gravity and drip from its lowest point. This dripping when idling and directly after stopping the engine cannot be prevented excepting by curving the inlet manifold branches downward, so the heavy constituents will run into the engine instead of back into the carbureter. The method mentioned overcomes the dripping, but the heavy parts of the gasoline finally find their way past the pistons into the crank case, thinning out the oil and thus reducing its lubricating value. Even under the most favorable conditions of carburation a large part of the present-day gasoline finally mixes with the oil of the engine; this calls for a frequent draining of the oiling system, and replenishment with fresh oil.

The float of a carbureter, in order to float in the gasoline, must be lighter than the latter; in practice both hollow metallic floats and cork floats are used. Metallic floats are usually made in two pieces of brass or copper, the joint being soldered. Cork floats are made from a solid piece of cork, and as this material will absorb gasoline and thus become heavier, it is thickly coated with shellac varnish on the outside to render it impervious to gasoline.

72. Several of the common forms of float-feed construction are shown diagrammatically in Fig. 13.

In view (*a*), the float *a* is rigidly attached to a lever *b* hinged at *c*; to the other end of the lever is hinged the float valve *d*. The gasoline enters at *e*. The rising of the float under the inflow of the gasoline into the float chamber depresses the float valve *d*, thereby finally stopping the inflow.

In view (*b*), the float *a* bears on the long arm of two levers *b* that are fulcrumed at *c*; the short arms of the two levers bear against a shoulder of the float valve *d*. This valve is made rather heavy, and its weight is assisted by the tension of a helical spring *e* so as to overbalance slightly the downward force of the float when the float chamber is filled to the right height with gasoline. The tension of the spring may be adjusted by means of the screw *f*. The rising of the float *a* permits the float valve *d* finally to stop the flow of gasoline.

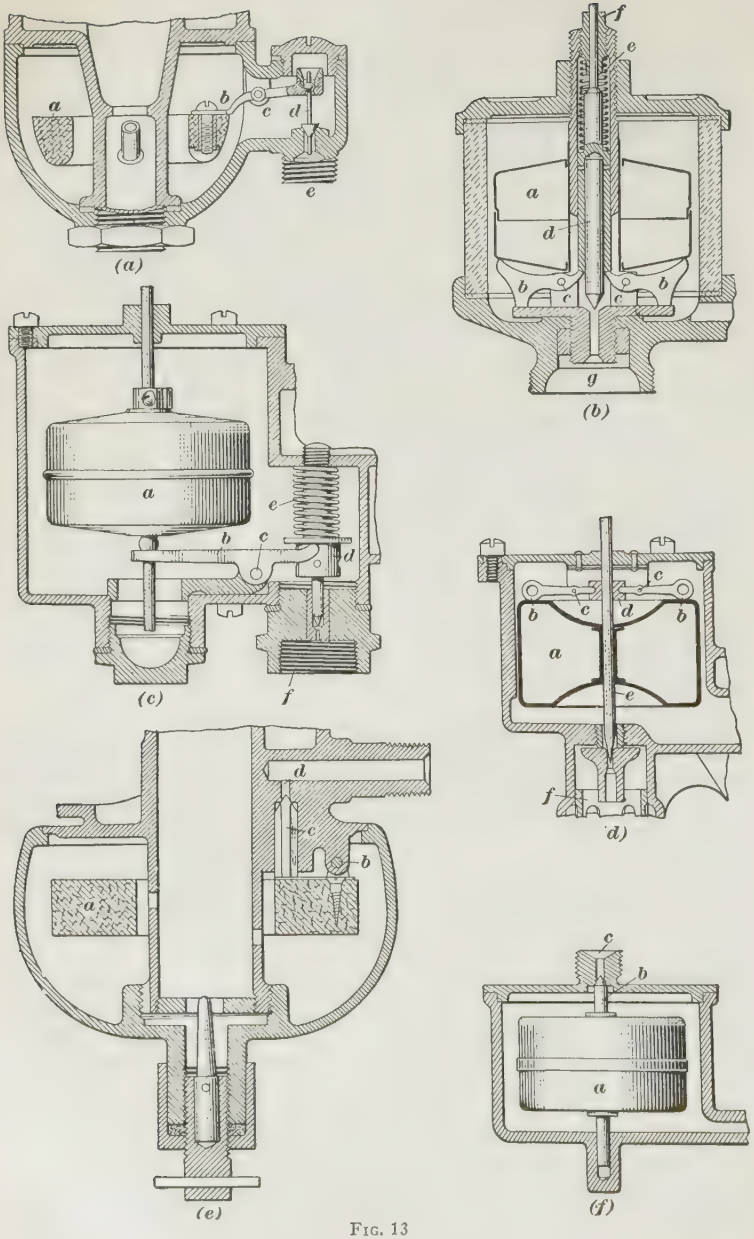

FIG. 13

In view (*c*), the float *a* rests on the long arm of a single lever *b* fulcrumed at *c*; the short arm of the lever bears against a shoulder formed on the float valve *d*. This float valve may be made heavy enough to overcome the downward force of the float, or it may be made light and fitted with a spring *e*. The gasoline enters at *f*. The rise of the float *a* permits the float valve *d* to stop the inflow of the gasoline.

In view (*d*) is shown a float-feed construction that is very common. The upper surface of the float *a* when rising with the incoming gasoline engages the outer ends of the two levers *b*, which are fulcrumed at *c*; the inner end of the levers engages a slot in a collar *d* fastened to the float valve *e*, which works freely through the float *a*. In consequence, the rising of the float depresses the float valve until the inflow of gasoline entering at *f* is stopped. The outer ends of the levers *b* are made heavy to overbalance the weight of the float valve, in order that it may rise when the float sinks.

A very simple float-feed construction is shown in view (*e*). The float *a* is hinged at *b* and bears directly against the float valve *c*. The rising of the float pushes the float valve upwards, finally closing the opening *d* through which the gasoline enters.

A float-feed construction of the simplest type is shown in view (*f*). Here the float *a* and float valve *b* are integral; the rising of the float finally closes the opening *c* through which the gasoline enters the float chamber. This construction is very rare.

73. When cranking an engine by hand or by an electric motor in order to start it, the suction and velocity of air through the carbureter are generally not great enough to draw sufficient fuel from the spray nozzle of a float-feed carbureter to make a mixture rich enough to ignite, if the carbureter is set for a correct mixture when running. This is principally due to the small amount of highly volatile constituents in present-day gasoline, and the small amount of such gasoline drawn from the carbureter nozzle at cranking speeds, which produces a mixture entirely too weak to ignite. Therefore, some means must be provided for temporarily enriching the

mixture for starting, which means should be under the driver's control and so arranged that its use does not permanently change the normal carbureter adjustment for running.

74. Formerly it was the practice to provide the float chamber with a handy means of depressing the float, thereby permitting some extra gasoline to overflow from the nozzle into the air intake; operating by this means was spoken of as *tickling* or *priming the carbureter.* Experience has shown, however, that priming the carbureter is rather unsatisfactory in many cases, and that better results in quick starting of a cold engine are obtained by means of a hand-controlled shutter in the air intake, the shutter also permitting a variable temporary enrichment of the mixture without interference with the normal carbureter adjustment. This air-intake shutter is found incorporated in practically all modern carbureters, and is usually called a *choke valve* or *strangling valve,* and its use is spoken of as *choking* or *strangling the carbureter.* The partial or entire closing of the air intake causes the downwardly moving engine pistons on their suction stroke to form a rather high vacuum at the gasoline nozzle, thereby greatly increasing the gasoline flow from the nozzle.

As soon as the engine fires, the strangling valve must be opened a little, and it must be opened entirely as the engine becomes warm, as otherwise an overrich mixture will be drawn into the cylinders and the engine therefore will begin to choke and perhaps even stop firing; this is colloquially known as *choking the engine to death.*

Some carbureters are provided with a gasoline nozzle the opening of which is adjustable through a needle valve from the driver's seat, thus providing a ready means of temporarily enriching the mixture. Occasionally an interconnected choke valve and gasoline nozzle needle valve is used.

COMPENSATING CARBURETERS

75. Introduction.—The greatest problem in carburation is to design a carbureter so that it will give the proper and homogeneous mixture of gasoline vapor and air required at all

engine speeds and at all throttle openings. A float-feed carbureter of the elementary form shown in Fig. 10 cannot do this, because the flow of gasoline from the gasoline nozzle increases at a greater rate than the flow of air through the air tube when the engine is speeded up. In other words, if the ratio of gasoline vapor to air is correct at a low engine speed, it will be too large at a higher speed, or, as it is commonly expressed, the mixture becomes *too rich*. This is just the opposite of the way the mixture should be; it will be most satisfactory if it is a little rich at very low engine speeds and becomes less rich as the engine speed increases. This statement about a carbureter of the elementary form shown in Fig. 10 must not be construed to mean that it is impossible to use a form so simple; its true meaning is that it will furnish a mixture substantially correct over only a rather narrow range of engine speed and throttle opening. Thus, if the nozzle and the air tube are correctly proportioned for an engine speed of 400 revolutions per minute, the carbureter will probably deliver a substantially correct, although theoretically incorrect, mixture anywhere between perhaps 250 and 500 revolutions per minute.

The quantity of mixture flowing from the carbureter to the engine is governed by a hand-operated throttle valve, which is incorporated in the carbureter. Opening the carbureter throttle allows more mixture to pass into the cylinders, which thereby have the force with which the crankshaft is turned increased. Conversely, the partial closing of the throttle valve cuts down the quantity of the mixture passing into the cylinders, and this decreases the force with which the crankshaft is turned. The opening of the carbureter throttle may increase the engine speed or car speed or may simply increase the work done in each cylinder on the explosion stroke while the engine actually slows down; whether the engine will speed up or slow down with an increased throttle opening depends entirely on the load. Thus, assuming the car to be running slowly in high gear on the level, an opening of the throttle may increase the car speed; upon striking a fairly steep hill that can be climbed on high gear, however, the car will slow down to a low speed even though the throttle is opened wide.

76. A carbureter that controls the mixture over only a very small speed and throttle-opening range is said to lack *flexibility;* conversely, a carbureter controlling the mixture properly over a very large speed and throttle-opening range is said to be very flexible.

Flexibility in a carbureter can be secured only by providing means of compensating for the more rapidly increasing flow of the fuel over that of the air as the engine speed or throttle opening increases. A carbureter provided with such means is called a *compensating carbureter,* and if the means adopted work without attention of the operator, it becomes an *automatic compensating carbureter.*

77. Methods of Compensation.—Carbureter compensation may be accomplished, in general, in several ways: (1) By reducing the rate of fuel flow as the throttle opening increases; (2) by increasing the air supply as the throttle opening increases; (3) by combining a number of air tubes and fuel jets into a single carbureter; and (4) by a combination of methods 1, 2, and 3.

78. There are a number of ways in which the first method of compensation may be accomplished. Among these may be mentioned a needle valve applied to the gasoline nozzle to control the gasoline flow and intended to be operated by hand by the operator from the driver's seat. Very good results can be obtained in this way by an expert operator, but the continual attention that the carbureter requires while the car is being driven makes this method of hand compensation undesirable. An automatic compensation can, however, be effected by constructing the fuel nozzle or fuel jet in such a way that the ratio of fuel weight to air weight will either remain constant or actually decrease instead of increase at high motor speeds or large throttle openings; a fuel nozzle thus constructed is called a *compensating jet.*

The second method of compensation, which is accomplished by means of a valve applied to the air tube and controlled by hand from the driver's seat, was used to some extent in the

early days of the automobile industry; however, it is open to the objection of requiring constant attention.

The third method of compensation, when worked out properly, will give an automatic compensating carbureter, which, while theoretically inexact in its compensation, will be sufficiently exact for all practical purposes.

The fourth method of compensation is employed in the majority of compensating carbureters. There are many ways in which compensation may be secured, most common among them being a weakening of the suction around the fuel nozzle at the higher motor speeds or larger throttle openings, generally by an inwardly opening valve that admits pure air directly to the mixing chamber, such a valve being called an *auxiliary air valve*. In another way, the fuel-jet orifice is mechanically enlarged or reduced by an interconnection to either the throttle valve or the auxiliary air valve, this fuel control working in conjunction with an auxiliary air valve. In still another way, use is made of an air tube of which the cross-sectional area is changed, thereby lessening the suction at the jet orifice at high motor speeds or large throttle openings. This kind of a device is called an *expanding carbureter;* it retards the fuel flow from the nozzle without decreasing the volume of air passing through the air tube. In yet another way, the fuel flow is controlled by a tapered needle, called a *metering pin,* that is placed centrally in the orifice of the jet; by either moving this pin or the jet in the direction of its length the annular opening through which the fuel flows is either enlarged or restricted. This metering pin or the jet is moved by the motion of an air valve, by a mechanical interconnection to the throttle valve, or by the auxiliary air valve.

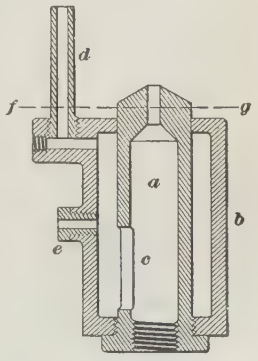

FIG. 14

79. Compensating Jets.—One way in which a compensating jet may be constructed is shown diagrammatically in

Fig. 14. The nozzle, or jet, *a* is surrounded by a casing *b*, with which it is in communication through a slot *c*. This casing is open to the atmosphere through a pipe *d*, and communicates with the float chamber through an opening in the plug *e*. With the engine standing idle, the fuel entirely fills the casing *b* and fills the nozzle to the level of the dotted line *f g*. The open end of the pipe *d* does not communicate in any way with the air tube of the carbureter. As soon as the engine is started, a partial vacuum is created at the orifice of the jet and fuel begins to flow from it. As the vacuum increases under an increase of engine speed, the level of the fuel in the casing *b* becomes lower, because the fuel passes faster from the jet orifice than it enters the casing *b* through the opening of the plug *e*, the fuel flow through this plug being under a constant pressure existing in the float chamber. The effect of lowering the fuel level in *b* is that the fuel has to be raised a greater distance, whereby the fuel flow from the jet orifice is reduced. As the engine speed, and hence the vacuum at the jet orifice, is still further increased, the fuel level in the casing *b* finally falls below the upper edge of the slot *c* and air can now enter the inside of the jet, through the tube *d*, thereby more and more counteracting the greater vacuum at the jet orifice and thus reducing still further the rate of fuel flow.

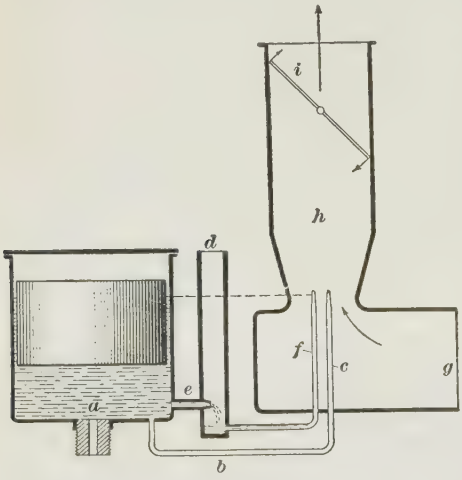

Fig. 15

This compensating jet is used in some Holley carbureters.

80. A method of constructing a compensating jet by means of two fuel orifices is shown diagrammatically in Fig. 15. In

this illustration the float chamber *a* is connected by a passage *b* with the fuel jet *c*; a fuel well *d* open at the top communicates through a small opening at *e* with the float chamber *a*, and its bottom is connected to the second fuel jet *f*. In the actual carbureter employing this method of compensation, the second fuel jet surrounds the first jet; this, however, does not change the principle involved. The combined area of the two orifices is made of sufficient size for a low engine speed. Air enters the air tube at the inlet *g* and flows past the nozzles into the mixing chamber *h*; the mixture flowing to the engine is controlled by the throttle valve *i*.

The action of the two jets is as follows: When the engine is idle, the fuel stands at the same level in the float chamber *a*, the well *d*, and the jets, or nozzles, *c* and *f*. When the engine is started, both fuel jets are discharging while the motor speed is moderate. As soon as the engine speeds up, the vacuum at the jet orifices increases; the jet *c* increases its discharge, but the rate of flow from the jet *f* decreases, because the fuel level in the well *d* is lowered by reason of the jet *f* drawing the fuel faster from the well than it can flow to the well through the opening *e*.

The two jets and the opening *e* are so proportioned that the rate of fuel flow will decrease faster than the rate of flow of the air as the engine speed increases, thus giving a rich mixture at low speeds and a leaner mixture at high speeds.

The principle of compensation just described is employed in the Zenith carbureter.

81. Compensating by Multiple Air Tubes and Fuel Jets.—As has been stated, a carbureter can be compensated by constructing it with several air tubes, each of which has its own jet. Such a carbureter is called, in general, a *multi-stage carbureter,* and is virtually a combination of two or more carbureters, fed from a single float chamber, which successively come into action, supplementing one another.

82. Compensating by Combined Fuel and Air Regulation.—Many of the American carbureters depend on one or more auxiliary air valves to maintain a correct mixture

at all engine speeds and throttle openings. The general construction is shown in diagrammatic form in Fig. 16. The fuel from the supply tank flows in at *a* and passes into the float chamber until the float *b* rises so as to close the float valve *c* when the level of the fuel nearly reaches the top of the spray nozzle *d*. A comparatively small air intake, as shown at *e*, is connected to the mixing chamber *f* by an open passage. An auxiliary air intake is closed by the compensating automatic air valve *g* when the suction produced by the piston and hence the demand for mixture are light; but when the

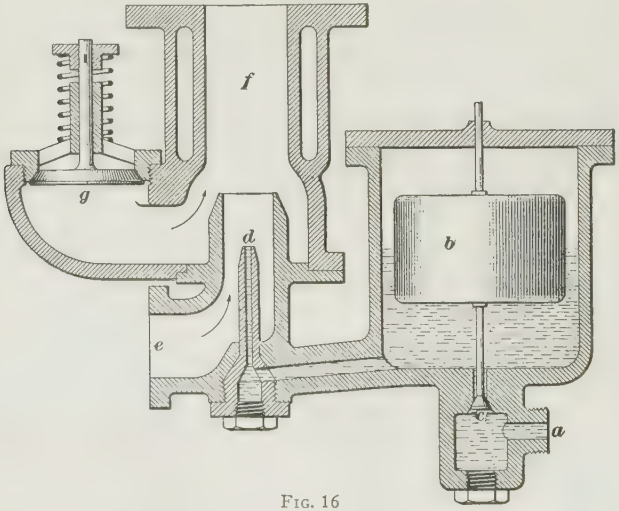

FIG. 16

engine is drawing mixture rapidly, the suction is sufficient to draw the spring-closed compensating air valve *g* open and automatically admit more air. This admission of air through the compensating valve restricts the suction at the spray nozzle *d* and also supplies pure air to dilute the overrich mixture formed in the small air passage leading from the open intake *e* past the spray nozzle into the mixing chamber.

83. A compensating auxiliary air valve is not necessarily a poppet valve, such as is shown in Fig. 16. It may be in the form of a flat strip of metal fastened at one end and lying over

the auxiliary air opening; or, the auxiliary air admission may be controlled by a series of balls closing, by their weight, a series of auxiliary air openings and opening them in succession as the suction in the air tube around the fuel jet increases. Still another form of auxiliary air valve resembles a shutter placed in the auxiliary air intake, which shutter is mechanically connected to the throttle valve, so that the opening of the throttle valve also opens the passage through the auxiliary air intake a proportionate amount.

84. In some carbureters, the fuel-jet discharge is mechanically controlled by the opening of the throttle valve, which action withdraws a tapered metering pin from the nozzle so as to increase the fuel orifice as the throttle opening is increased and to decrease the area of the orifice as the throttle is closed. On first thought, it would seem that this practice is a contradiction of the statement previously made; namely, that the rate of fuel flow from a nozzle increases at a greater rate than the rate of air flow past the nozzle with a given increase of the suction at the nozzle. This is not the case, however, for the following reason: In a carbureter with mechanical control of the fuel-jet opening, the air tube surrounding the fuel jet, as well as the fuel-jet opening, is proportioned to suit a high motor speed. In consequence, at a low motor speed, the fuel-jet opening is entirely too large, even though the suction has been decreased, and hence mechanical control of the fuel-jet opening is resorted to in order to obtain a correct ratio of fuel and air at all openings. Carbureters of the type under discussion are usually fitted with a very large auxiliary air valve, so as to lessen materially the increase in suction as the motor speed or the throttle opening is increased; in fact, the auxiliary air valve may be made so large and to open so far as to weaken the suction to such an extent that a fixed size of nozzle may pass insufficient fuel at high motor speed, thus calling for a large nozzle with mechanical control of the orifice.

The manner in which the throttle valve and the metering pin are interconnected is shown in its most elementary form in Fig. 17. A small crank *a* on the throttle-valve shaft *b* is con-

nected by a link *c* to a tapered metering pin *d*. Obviously, opening the throttle valve will pull the pin *d* upwards, thereby increasing the area of the annular opening through which the fuel passes into the mixing chamber.

The interconnection of the throttle and the metering pin is not necessarily on the inside of the mixing chamber, but may be on the outside of the carbureter, and may be effected in many different ways.

85. Instead of arranging carbureters so that the throttle valve and the metering pin interconnect, they may be so

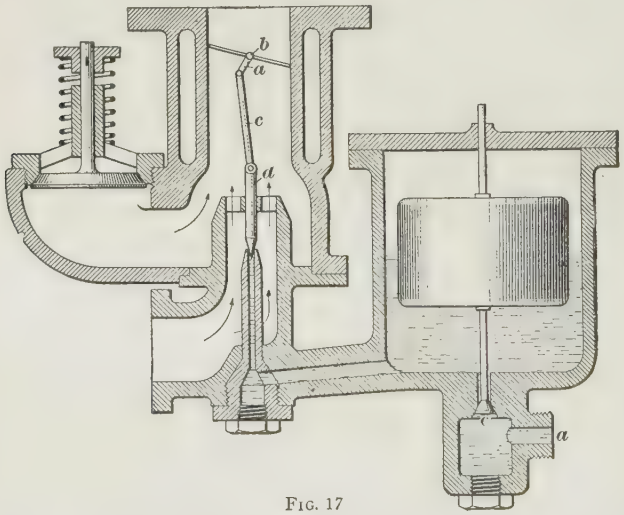

FIG. 17

arranged as to have the auxiliary air valve move the metering pin outwards from the jet orifice as that valve opens to admit more air and weaken the suction.

86. Weakening the suction at the jet at the higher motor speeds, in order to reduce the rate of flow of the fuel, by enlarging the air passage may be accomplished in various ways. In one construction, an iris diaphragm of the form used in the shutter of most photographic cameras is placed at the level of the fuel-jet orifice and central therewith; the diaphragm is then connected to the throttle valve in such a way that the opening

of the throttle causes the diaphragm to open out so as to give a larger air passage. Conversely, the closing of the throttle contracts the diaphragm. This form of control is now rare, as it is rather expensive to construct. A more usual construction, employed in Tillotson carbureters, is to use an air passage with two yielding walls, in the form of flat metallic strips. Or, a shutter automatically raised or lowered by any change in the vacuum of the fuel jet, may be used for changing the air opening; this is done in the carbureter used in many Hudson cars.

87. The principle involved in compensating by means of a metering pin attached to an air valve is shown diagrammatically in Fig. 18. The gasoline nozzle *a* and also the air inlet are proportioned for a high motor speed or a full-throttle opening; consequently, the fuel orifice will be entirely too large for low motor speeds or small throttle openings. To compensate for this, a tapered metering pin *b* is rigidly attached to an air valve *c* that is free to slide inside of a casing *d* forming part of the carbureter mixing chamber. This casing has at its lower end a number of slots through which air can pass to the mixing chamber in an amount determined by the up or down position of the air valve. A fine hole *e* is drilled at the bottom of the air valve opposite each slot in the casing *d*, and the holes *e* and the slots are kept in register by a pin fastened to the air valve and entering one of the slots.

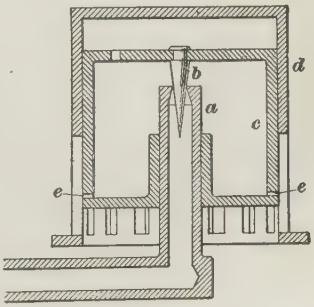

FIG. 18

When the air valve lifts as the motor speed or throttle opening is increased, the metering pin is withdrawn from the fuel nozzle; consequently, more fuel will pass from the nozzle, and, trickling down, will pass out the holes *e*, where it meets the air streams passing through the slots in the casing *d*. The lifting of the air valve increases at the same time the area of opening of the air passages; hence, more air can pass to the mixing

chamber. By correctly proportioning the taper of the metering pin, a mixture correct for all engine speeds and throttle openings can be obtained.

The combination of a metering pin with an air valve and fuel jet may be worked out in many different ways; Fig. 18 is intended merely to show the principle involved.

88. In designing a carbureter with a compensating auxiliary air valve, it is possible to make this valve so large and to cause it to open so far at high motor speeds or large throttle openings that not enough fuel can pass a single nozzle of fixed size. A second, or even a third, nozzle may then be brought into action in order to supply sufficient fuel at high motor speeds or large throttle openings. A carbureter having several nozzles so arranged as to come successively into action, working in conjunction with each other, is called a *multiple-jet carbureter*. Such a carbureter must not be confused with one built with several nozzles working in conjunction with one another all the time, which plan is sometimes adopted in order to break the fuel into spray in a better manner than usually obtains with a single fuel orifice.

89. While other methods of compensating than are here explained in detail are in use, they are usually only modifications involving no radical departures from the methods given.

FORMS OF CARBURETERS
(PART 1)

CONSTRUCTION AND ADJUSTMENT

ZENITH CARBURETERS

VERTICAL CARBURETER, MODEL O

1. Construction and Operation.—The Zenith Carbureter Company, Detroit, Michigan, builds several models of carbureters, all of the compensating jet type. These carbureters are manufactured as single and as duplex devices, the former being intended for four-cylinder and six-cylinder engines, while the latter are designed for eight-cylinder and twelve-cylinder engines. The duplex carbureters are in effect two single carbureters combined in one, a single float chamber supplying fuel to both carbureters, and each serving one cylinder block.

Like many other makes, the Zenith carbureters are made in vertical and horizontal patterns. A vertical carbureter may be defined as one in which the carbureter passage containing the throttle valve is vertical; such a carbureter is generally used with engines having a separate intake manifold. A horizontal carbureter in general is used with block-cast cylinders having the gas-inlet passages cored in the cylinder block, the carbureter having a horizontal passage in the carbureter body, in which the throttle valve is placed. There are exceptions, however, as to the application of horizontal and vertical carbu-

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reters; thus, a vertical carbureter is sometimes applied to block-cast cylinders without an intake manifold.

2. In Fig. 1 is shown in perspective section the Model O Zenith single carbureter, which is of the vertical type. As in all other Zenith carbureters, there are two gasoline jets, the main jet *a* being placed centrally within the cap jet *b*, and both being centered in the Venturi tube *c*. The gasoline pipe is connected at *d*, and the fuel is maintained at the correct level by the usual float *e*. Air enters the carbureter at the air inlet *f*, the incoming air being usually preheated by passing over the exhaust pipe. The atmospheric well *g* is situated between the float chamber and the two jets, and receives its fuel supply through the compensating jet, or compensator, *h*. The so-called priming plug *i* having a tubular extension is placed in the atmospheric well and connects, through the passage *k*, with the space above the throttle valve *i* when the latter is only slightly opened; the gasoline required to keep the engine going at idling speed is drawn from the well *g*, and the mixture can be regulated by the slow-speed screw *m*. This screw by admitting air past its seat determines the vacuum in the space between the priming plug *i* and the passage *k*, and therefore the amount of fuel that will be forced by the atmospheric pressure through the priming plug *i*, thus regulating the idling mixture. The well *g* is open to the atmosphere

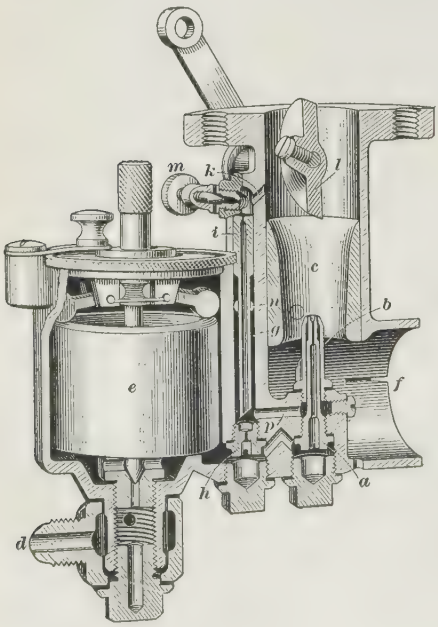


FIG. 1

through the hole *n*; therefore, with the engine not running, the gasoline stands at the same level in the idling well and the float chamber.

3. With the engine running faster than its idling speed, air preheated by being passed over the hot exhaust pipe of the engine enters the air intake *f*, Fig. 1, of the carbureter. The partial vacuum found at the throat of the Venturi tube *c* during the suction strokes of the engine, causes gasoline from the float chamber to pass out of the annular opening between the orifice of the cap jet and the outside of the main-jet tip. The main jet *a* is directly connected with the fuel in the float chamber, and the flow of gasoline from this jet will vary directly with the suction, which, of course, varies likewise with the speed of the engine. The higher the engine speed, therefore, the greater the suction, and the more fuel passes through the main jet *a*. The same is true of the air flowing through the Venturi, or choke, tube *c*, but the Venturi tube and jet *a* are so proportioned that under increasing speed and suction the flow of fuel increases more rapidly than the flow of air. The result is a rich mixture at high engine speeds.

4. The compensating jet *h*, Fig. 1, is also directly connected with the fuel chamber, but, as shown in the illustration, does not project upwards into the air stream flowing past toward the main jet *a*. Instead, it empties into a well that is open to the atmosphere at *n*, and, on this account, the jet *h* is not affected by suction. The amount of fuel that it deposits in the opening well *g* is determined entirely by the height of the fuel level in the float chamber, which level is kept constant by the float *e*, and the size of the hole in the jet *h*, which, of course, also remains constant. It follows then that the compensating jet *h* provides a constant amount of fuel to the open well *g* under all conditions of engine speed and suction. In other words, its flow does not vary.

5. The cap jet *b*, Fig. 1, which surrounds the main jet *a*, projects into the air stream flowing through the Venturi tube *c*, and is in connection with the open well *g* by a drilled channel hole *p*. While the opening at the top of this jet is affected by

suction, it can deliver only as much fuel to the air stream as is delivered to the open well *g* by the compensating jet *h*, and, therefore, the flow of fuel from this opening is constant. As the air flow increases with the speed and suction, and the fuel flow from the compensating jet *h*, open well *g*, and cap jet *b* is constant, the result is that the cap jet *b* delivers a lean mixture at high speeds. This leaning of the mixture at the cap jet, in conjunction with the enriching of the mixture at the main jet *a*, produces a mixture correctly proportioned for high speeds.

6. Under normal conditions of working, the priming plug *i*, Fig. 1, has no effect on the carbureter action; it is of service only during starting and when the engine is idling. When the engine is stopped the gasoline rises in the atmospheric well to the same level as in the float chamber. When the engine is cranked with the throttle *l* nearly closed, the suction in the passage *k* draws fuel from the well *g* through the primary plug *i*, and into the passage *k* to the engine cylinders, sufficient air passing by the seat of the slow-speed screw *m* to give a rich mixture for starting. With the engine idling there is practically no suction exerted at the jets, and hence the fuel is supplied almost entirely by the atmospheric well through the passage *k*.

7. Adjustments.—When a Zenith carbureter has once been fitted to the engine and supplied with the correct sizes of jets and Venturi tube, the only adjustment supposed to be made by the operator is for the idling speed. If the engine fails to keep going at idling speed after being started, the screw *m*, Fig. 1, is screwed inwards, thereby enriching the mixture, until the engine runs steadily; on the other hand, if the engine rolls, that is, periodically speeds up and slows down without change of the throttle position, the mixture is too rich for idling, and the screw *m* is slowly turned outwards until the engine runs steadily. The exact position of the screw *m* is found by trial, by moving it a little at a time and noting the effect on the idling of the engine.

8. Zenith carbureters are all of the fixed-adjustment type, but certain changes in the quality of the mixture of gasoline

and air can be effected by changing the jets and the Venturi tube. The main jets and compensating plugs are numbered, the number stamped thereon representing the size of the nozzle opening in hundredths of a millimeter. A millimeter is a metric measure of length and is approximately $\frac{1}{25}$ of an inch. Thus, a compensator number 105 has a hole $\frac{105}{100}$ of a millimeter in diameter, and a main jet numbered 100 has a hole $\frac{100}{100}$, or 1, millimeter in diameter. In adjusting Zenith carbureters the cap jets are not changed. The Venturi tubes are also numbered, their throat diameter being given in millimeters.

If the Venturi tube is too large, the engine will not accelerate promptly upon opening the throttle, even if a larger compensating plug is fitted; if the Venturi tube is too small the engine will accelerate promptly, but will not give the highest power. The obvious remedy is to change to a smaller or a larger Venturi tube, respectively.

The size of the main jet exerts its greatest influence at high engine speeds; if the main jet is too large, at high speeds on a level road the engine will run irregularly on account of the mixture being overrich. If the main jet is too small, there may be back-firing into the carbureter at high speed; at any rate, the car will not attain full speed.

The compensating jet *h* at the bottom of the atmospheric well exerts its greatest influence at the lower engine speeds. The test for the correct size of the compensator is best made on a hill, as regular in grade and as long as possible, by driving with a wide-open throttle on high gear. If the compensator is too small, the mixture will be too lean, causing missing of the engine and a jerky action; if the compensator is too large, the engine will run irregularly, and explosions may be produced in the muffler; in fact, all indications will be those of an overrich mixture.

ZENITH CARBURETERS, MODELS HN, OD, U, T, AND TX

9. Zenith Carbureters, Models HN and OD.—The Model HN Zenith device is a single carbureter of the horizontal type; it is shown in cross-section in Fig. 2. The fuel enters at *a*; the compensator is shown at *b* at the bottom of the idling well;

the cap jet *c* surrounds the main jet *d*. The Venturi tube, or choke tube, *c* is placed horizontally in this carbureter, with the cap jet and the main jet extending into it at its throat; the throttle valve is shown at *f* and the throttle-valve lever at *g*. The idling adjustment is made by means of the milled-head sleeve *h*; turning this down enriches the mixture for idling, and turning it up weakens the mixture. The operation of the compensating jet, main jet, compensator, etc., and the changes

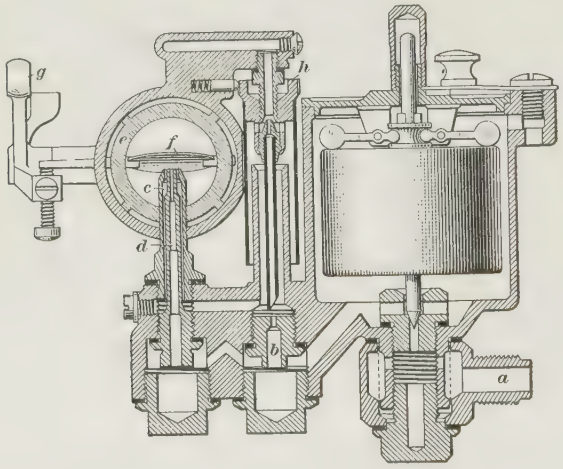


FIG. 2

in mixture that can be effected, are identical with those of other Zenith carbureters.

10. The Model OD Zenith carbureter is duplex, and is shown in Fig. 3 in perspective. It has a single float chamber *a*, the gasoline inlet being at *b*, and two Venturi-tube chambers *c*, each of which contains a throttle valve; both throttle valves are operated simultaneously from the throttle-valve lever *d*. Each half of the carbureter has its own main jet, cap jet, and compensator, and also its own atmosphere well, one of which is shown at *e*; the idling wells are each supplied with their own slow-speed screw *f*. This carbureter being intended for V-type engines, each Venturi-tube chamber *c* is connected to its own cylinder block.

The operation or adjustment of the halves of the duplex Zenith carbureter does not differ from that of the Zenith single carbureters, except that the idling adjustment is made independently for each cylinder block, the spark-plug wires being disconnected from the cylinder block the carbureter for which is not undergoing adjustment. In Zenith duplex carbureters the two throttle valves, while moving simultaneously, can be independently adjusted to give the same idling speed to each cylinder block assembly, by means of the adjusting screws *g* and throttle stop-screw *h*.

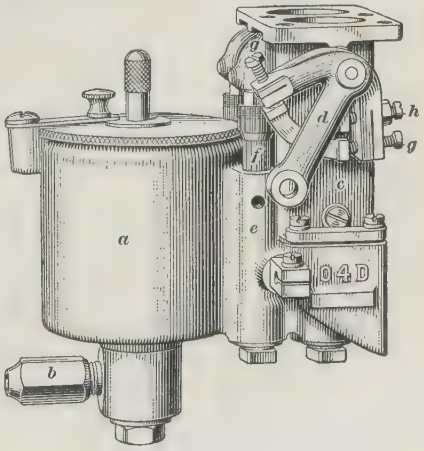


FIG. 3

11. Zenith Carbureters, Models U, T, and TX.—Models U, T, and TX Zenith carbureters operate on the same principle as the carbureters already described, and the same instructions for the operation and adjustment of the other models, as already given, will apply to these types. Models U, T, and TX differ from the other makes mainly in constructive details, being made in the following three separate groups of parts: (*a*) A float chamber, or bowl, carrying the float mechanism and the system of fuel nozzles; (*b*) the carbureting chamber, or barrel, containing the Venturi tube and the throttle; (*c*) an air intake containing a strangling device and a temperature regulator. This three-piece construction permits of more economical manufacturing, and also of the working out of some of the parts to greater detail.

STROMBERG PLAIN-TUBE CARBURETERS

FUNDAMENTAL FEATURES

12. Construction.—The Stromberg Motor Devices Company, Chicago, Illinois, make many different models of carbureters with a single auxiliary air valve, but also build several models without any air valve, which they classify as plain-tube carbureters.

The Stromberg plain-tube carbureters compensate for different engine speeds by means of what are called air-bled jets, which have been proved experimentally, when properly constructed, to give a constant proportion of gasoline and air at all speeds.

The principle of construction of the air-bled jet is shown in Fig. 4. Placed in the center of the usual Venturi tube *a*, through which the air passes at high velocity, is a second but smaller Venturi tube *b* the mouth of which is at the throat of the tube *a*. Eight very small holes *c* are drilled through the wall of the tube *b* slightly above its throat; it will be understood that owing to the two Venturi tubes being in series a very high air velocity is obtained under the suction of the engine at the throat of the Venturi tube *b*, even at fairly low engine speeds, which greatly aids the atomization of any fuel leaving the jet holes *c*. These holes *c* communicate with a passage *d* leading to the float chamber of the carbureter; this passage *d*, through holes *e* drilled into its wall, communicates with the air by way of the passage *f* and holes in the cap *g*.

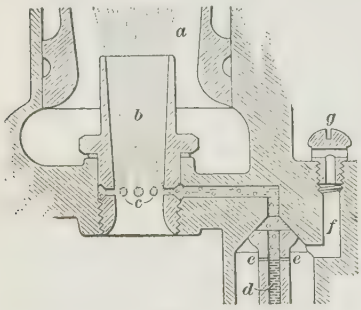


FIG. 4

13. Operation.—With the engine running, liquid fuel is forced by atmospheric pressure, due to the vacuum in the two Venturi tubes *a* and *b*, Fig. 4, up the passage *d* to the holes *e*,

where air enters and mixes with the liquid gasoline, changing it to a finely divided emulsion, or froth, which emulsion passes through the jets *c* into the Venturi tube *b*, where it is further atomized and diluted by the air passing through the tube *b* at high velocity.

The finely divided mixture of gasoline vapor and air leaving the mouth of the tube *b* at the throat of the Venturi tube *a* is still further atomized by the air passing through *a*, and the mixture thence goes past the throttle valve (not shown) to the engine cylinders. As in all carbureters, changing of the gasoline globules into vapor is effected not only by atomization but also by vaporization, the latter being assisted by preheating the air admitted through the Venturi tubes, the preheating being done by passing the air over the hot exhaust pipe.

To sum up, an air-bled jet delivers into the mixing chamber an emulsion consisting of very small globules of gasoline suspended in air, instead of liquid gasoline.

MODELS L, LB, M, AND MB CARBURETERS

14. Construction.—The general construction of the Stromberg plain-tube carbureters, models L, LB, M, and MB, is shown diagrammatically in Fig. 5. The models L and M are of the vertical type; the models LB and MB are of the horizontal type. The general principle of operation is the same in all four models, but the details of construction vary slightly.

The gasoline enters at *a* and passes into the float chamber *b*, whence it passes through an orifice at *c*, fitted with an adjustable needle valve *d*, into the passage *d'*. This is fitted with a plug having a central hole and communicating with an annular chamber *e* called the accelerating well; the so-called idling tube *f* receives gasoline through the small hole *g*; the accelerating well has three small holes drilled through its inner wall, a vent hole drilled through its upper end, and several small holes drilled through its lower end to communicate with the gasoline chamber *h* to which the fuel is supplied by the adjustable orifice *c*. The passage containing the idling tube *f* ter-

minates at a plug i located above the throttle j, when in its closed position.

The small Venturi tube is shown at k, and the large one at l; both Venturi tubes receive a preheated air supply through the air tube m provided with a strangling valve n for enriching the mixture, for starting the engine in cold weather, by strangling the air supply. The liquid gasoline for the emulsion of gasoline and air supplied to the small Venturi tube k is drawn

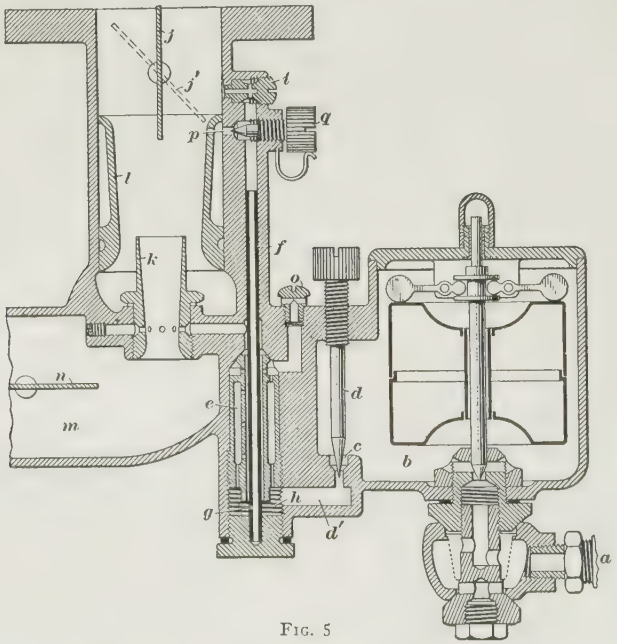


FIG. 5

from the chamber h through the annular opening between the idling tube f and the hole in the plug containing the accelerating well e. The air-admission plug o supplies the air for the air-bled jets in the Venturi tube k; an air opening at p fitted with a low-speed needle valve q supplies air to the gasoline passing out through the idling, or low-speed, plug i.

15. Operation.—The operation of the carbureter illustrated diagrammatically by Fig. 5 is as follows: When idling,

the throttle *j* is closed. Under this condition, gasoline is drawn from the chamber *h*, through the idling tube *f*, and mixes with air admitted through the passage *p*, the combustible mixture passing through the idling plug *i* into the space above the throttle and thence to the engine. When idling the two Venturi tubes *k*, *l* and the air-bled jets are out of action, and just enough air passes, at a very low velocity, through the Venturi tubes to supply that required for the idling mixture.

When the engine is speeded up by opening the throttle *j* slightly, the vacuum in the intake manifold of the engine is increased, and therefore the air-bled jets come into action; for very low throttle positions the mixture is fed to the intake by both the idling jet *i* and the air-bled jets. As the throttle is still further opened, the gasoline is drawn faster from the idling tube *f* than it can enter through the hole *g*, and consequently the idling jet automatically goes out of action, all the fuel now being supplied by the air-bled jets in the smaller Venturi tube *k*. It will be plain that the annular opening at *c* should be just large enough to keep the chamber *h* filled with gasoline at all motor speeds; this opening is regulated by trial by turning the adjusting screw *d* up to strengthen the mixture, and down to weaken it. The strength of the mixture for idling is adjusted by trial by means of the low-speed adjusting screw *q*, the throttle being fully closed for this.

16. It is a well-known fact that a carbureter set for a weak mixture, which means an economical mixture, will fail to give good acceleration, that is, will not permit a quick throttle opening and consequent quick response of the car. Quick acceleration can in practice be secured in two ways: By a permanent setting of the carbureter for a rich and hence very uneconomical mixture, or by temporarily enriching the mixture during acceleration and then returning to the former economical setting. The last alternative is employed in the Stromberg plain-tube carbureters, the accelerating well serving the purpose of temporarily enriching the mixture and automatically returning to an economical mixture after acceleration.

With the engine running at a constant speed corresponding

to a car speed of about 20 miles per hour, the accelerating well *e*, Fig. 5, is filled to the top with gasoline. But, if the engine speed is now increased suddenly, the gasoline is drawn faster from the chamber *h* than it can flow into it past the orifice *c*, and a deficiency of fuel would quickly exist in the chamber *h*, were it not that the accelerating well *e* discharges the fuel it holds, through the holes in its bottom head, into the chamber *h*, thereby temporarily doubling the normal rate of gasoline flow into the chamber *h* and thus supplying the fuel needed for acceleration. By the time the car has speeded up, sufficient fuel flows through the orifice *c* to supply the chamber *h* with all the fuel needed. When the car slows down, the accelerating well gradually fills again with gasoline and is ready for the next sudden acceleration.

17. The Stromberg models M and MB plain-tube carbureters operate exactly as described in connection with Fig. 5, the adjusting screw *d* being movable for adjustment by hand. In the models L and LB, however, a refinement is introduced to improve flexibility, by interconnecting the adjusting screw with the throttle valve. This refinement makes itself felt only at heavy pulling under a wide-open throttle, such as occurs in ascending a steep hill slowly on high gear. Under this condition a rich mixture is needed, while for very fast driving on an open throttle a much leaner mixture is required.

To show the interconnection between the throttle and adjusting screw, a perspective external view of a model L Stromberg carbureter is presented in Fig. 6.

A cam *a* is carried on the throttle-valve shaft; a roller *b* carried on the lever *c* pivoted at *d* bears against the cam *a*. The horizontal arm of the lever *c* is forked, as shown; on the fork rests the adjusting nut *e* screwed on the needle valve *e'*, which is free to move up and down, its downward travel being arrested, however, by an adjustable stop *f*, which can be turned up or down through part of a revolution by means of the pointer *g*. A helical spring inside the carbureter pushes the needle valve *e'* downwards. The combination of the cam *a*, lever *c*, and movable adjusting stop here shown is called the

economizer attachment by the makers of the carbureter, because it permits setting the carbureter for economical operation under average driving conditions.

18. To understand clearly the operation of the economizer attachment, it must be borne in mind that even for the highest normal car speed on the level, say 40 miles per hour, the throttle valve *j* does not come to the position shown in Fig. 5 in full lines, but approximately to that shown by the dotted line *j'*. The cam *a*, Fig. 6, has a notch *a'* cut into it in

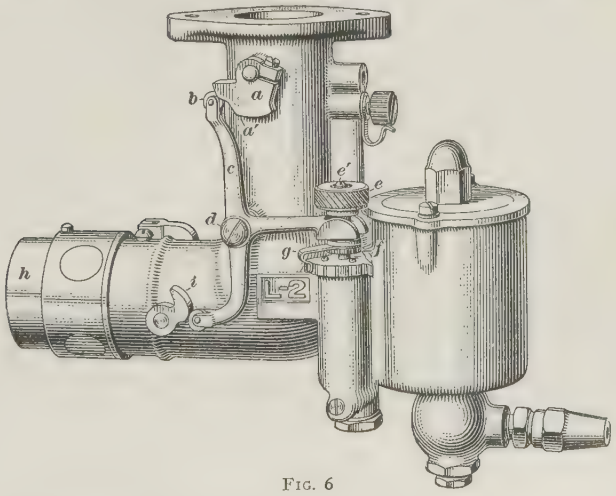


FIG. 6

such a position that the cam does not rock the lever *c* and lift the needle valve excepting at speeds below 10 miles and above 40 miles per hour on high gear. On ascending a steep hill on high gear, the throttle valve is opened to the limit (shown at *j* in Fig. 5); the adjusting nut and needle valve are thereby lifted, and hence the area of the orifice through which gasoline flows from the float chamber is greatly increased, thereby enriching the mixture as long as the throttle is kept in this position. A slight closure of the throttle valve permits the needle valve to drop back to its former economical setting.

The economizer attachment is also interconnected with the strangling valve in the air intake *h*, Fig. 6, the cam *i* on the

strangling-valve shaft being placed in such a position, and bearing against an arm of the lever *c* in such a manner, that a closing of the air-strangling valve by means of the dash or steering-post adjustment also increases the gasoline flow to the air-bled and idling jets, thus temporarily enriching the mixture by hand control.

19. Adjustments.—To adjust the Stromberg carbureters models L, LB, M, and MB for idling, the engine is started with the low-speed adjustment screw *q*, Fig. 5, approximately one-half turn off its seat. When the engine has warmed up, the screw *q* is turned out, that is, counter-clockwise, until the engine idles steadily. As a general rule, the proper idling adjustment is when the screw *q* is somewhere between one-half and one and one-half turns off its seat.

The adjusting screw *d* adjusts the mixture over the whole driving range; an approximate adjustment is obtained by turning it about three whole turns off its seat, which will probably give a rather rich mixture, and then screwing it in until trial shows a sufficiently weak mixture. Attention is called to the fact that the adjusting screw *d* is turned to the left on the models M and MB to enrich the mixture, while the adjusting nut *e*, Fig. 6, is turned to the right for the same purpose on the models L and LB.

20. The adjustment of a Stromberg plain-tube carbureter fitted with the economizer attachment, shown in Fig. 6, is as follows: With the spark retarded and the car running 20 miles per hour on high gear, the pointer *g* is set by trial to within one notch of the leanest mixture on which the engine will run steadily when warmed up; this will usually be about the third or fourth notch. Moving the pointer toward the left, or away from the float chamber, makes a leaner mixture, and to the right, makes a richer mixture. In some of the model LB Stromberg carbureters the pointer *g* is omitted; the stop limiting the drop of the needle valve is then set to the correct position at the factory. As there set, the drop equals that due to about two notches of the stop turned from its position where there is no clearance at all between the adjusting-

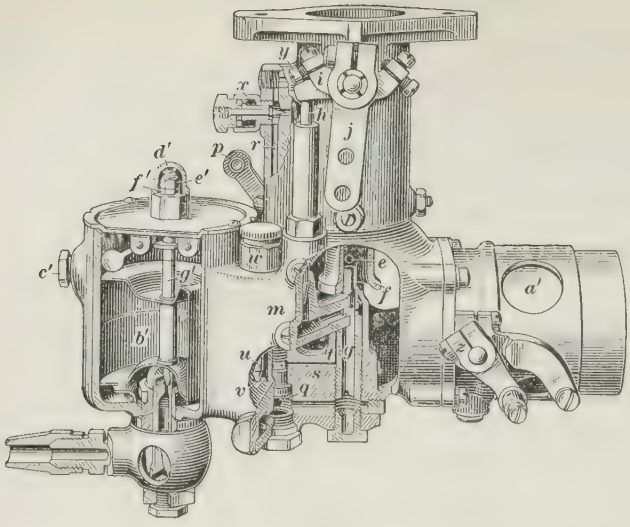
screw head and the adjustable needle-valve stop. In adjusting the economizer attachment, it is well to bear in mind that the needle-valve adjusting nut must first have been adjusted to give a satisfactory mixture for hill climbing on a wide-open throttle before the needle-valve stop is adjusted for a lean, that is, an economical, mixture.

MODEL O CARBURETERS

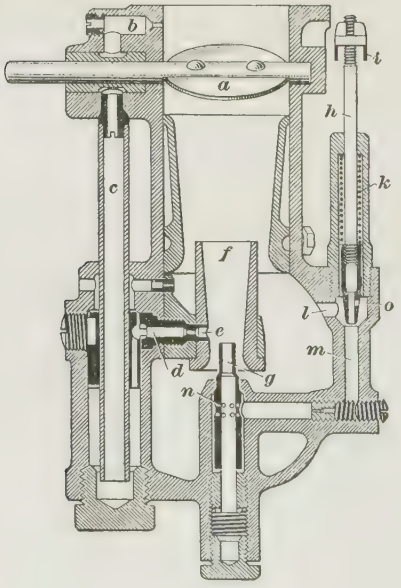
21. Construction and Operation.—The Stromberg, model O, carbureter, while representing a more recent development of the plain-tube carbureter, still retains many of the constructional details of the earlier models. It is built in both vertical and horizontal types, the vertical being designated as 0–1, 0–2, etc., and the horizontal as OS, OC, etc., according to their installation. The horizontal types, in construction and operation, are similar to the vertical types, having only such slight changes as result from the rearrangement of the elements. Consequently, a description of the vertical type will suffice for both.

Chief among the new features of the model O carbureter are the following: (*a*) The accelerating well, which releases the accelerating supply of gasoline according to the decrease of vacuum in the intake manifold, instead of the increase in the air velocity, as in the types already described; (*b*) the economizer, which permits the carbureter to operate on a very lean and economical mixture at the partly closed throttle position of average driving, but automatically gives the needed richer mixture when the full power of the engine is required; (*c*) a needle valve controlled from the dash, which provides a rich mixture for starting; and (*d*) a somewhat different construction of the idling feed.

22. An outside view of the carbureter is shown in Fig. 7 (*a*), which shows the casing partly cut away so as to reveal the main points of design of the interior. View (*b*) is a cross-section, which shows the economizing device and the acceleration well. Parts that appear in both views are given the same reference letters.



(a)



(b)

FIG. 7

The action of the accelerating well, which device is not shown in view (*a*), because it is on the opposite side of the carbureter from that shown, is as follows: When the throttle *a*, view (*b*), is closed, the vacuum in the intake manifold above the throttle acting upon the small opening *b*, causes gasoline to rise in the tube *c*. But when the throttle is opened suddenly and the vacuum in the intake manifold is lowered, the gasoline from the tube *c* discharges through the passage *d* and the opening *e*, also shown in view (*a*), into the opening of the Venturi tube *f*, where it is added to the mixture issuing from the main jet *g*, thus giving a better accelerating mixture.

23. The economizer device is shown in both views in Fig. 7. It consists of a taper-pointed metering pin *h*, which is raised by the fingers *i* when the throttle lever *j*, view (*a*), is moved to the left to close the throttle valve, and which is lowered by the spring *k* when the throttle is opened. This metering pin, in moving up and down, controls the amount of air that enters the opening *l* and passes through the channel *m* and the small holes *n* to the main gasoline jet *g*. When the throttle is open, the metering pin *h* rests on its seat, and the air entering the passage *m* is restricted to that which passes through the hole *o* drilled in the needle point of the pin. The restriction of the air supply at this point concentrates the suction at the main air intake and a richer mixture is produced. As the throttle closes, the metering pin is raised from its seat and a relatively larger air passage is opened to the channel *m*, and a weaker mixture at the spray nozzle results.

24. The auxiliary needle valve, which is not visible in Fig. 7, is operated by the lever *p*, shown in view (*a*). This valve simply controls a second gasoline passage, and, when raised, allows additional gasoline to pass to the spray nozzle. The opening leading from this auxiliary gasoline passage is shown at *q*. This valve is controlled from the dash, and is intended to be used in starting during ordinary weather conditions, or to give a temporary richer mixture in cold weather until the engine has warmed up properly.

The action of the idling tube *r* is already described in Art. 14 in connection with the earlier models. The construction used in the model O carbureter differs from that already described only in that gasoline is drawn from around the main spray nozzle by way of the passages *s* and *t*, instead of from the accelerating well. The high-speed needle valve is shown at *u*. This valve controls the orifice *v* by which gasoline passes from the float chamber to the spray nozzle. The position of this valve is adjusted by means of the knurled nut *w*.

25. Adjustment.—The adjustment of the Stromberg model O carbureter is as follows: The idling mixture at closed throttle for speeds below eight miles per hour is controlled by the knurled-headed screw *x*, Fig. 7 (*a*). If the carbureter is entirely out of adjustment, this screw should be turned out about half a turn from its fully closed position, and the engine started.

When the engine has warmed up properly, and the starting control buttons on the dash are pushed all the way in, the knurled head *x* should be turned out, or counter-clockwise, slowly until the engine idles smoothly. The proper adjustment will be obtained when the screw *x* is turned out from 8 to 10 notches. If the idling speed is too high after this low-speed adjustment has been made, it can be cut down to the proper point by unscrewing the throttle stop-screw *y*. If the idling speed is too low, the screw *y* should be turned in, or clockwise.

26. The high-speed and main driving adjustment is regulated by the knurled head *w* on the needle valve *u*, Fig. 7 (*a*). Before attempting to obtain the correct setting of this pin, the spark lever should be moved to the normal driving position, and the throttle lever on the steering wheel set to the position that will give a speed of about 25 miles per hour on a level road. The knurled head *w* should be turned down, or clockwise, slowly until the lowest point of the needle is reached at which the engine will run smoothly, and at its maximum speed at that throttle opening. This adjustment should serve for average driving.

When making long trips, or in very hot weather, it will probably be possible to turn the head *w* one or more notches to the right, and thus give a more economical mixture. When driving in cold weather, when short trips are mostly made, the engine heat will generally be below normal; then it will be advisable to turn the head *w* one notch to the left from the normal position.

The economizer device is properly adjusted when the carbureter is installed in the engine, and no further adjustment should be attempted. In case the economizer needle has been changed for some reason, it should be reset so that the total lift will be $\frac{9}{32}$ inch.

27. Two driving controls on the dash are provided for the model O carbureter. One of these, marked *Adj*, is connected to the lever *p*, Fig. 7 (*a*), and when pulled out opens a needle valve and feeds additional gasoline to the spray nozzle. This control should be used for starting in ordinary temperatures, and for temporary mixture regulation in colder weather. The extent to which it is necessary to pull this control out, when starting, depends on the temperature and on the grade of fuel used. As soon as the engine starts, the control button should be pushed in as far as possible and still keep the engine running smoothly.

The *Start* button on the dash is connected to the lever *z* and operates the choke valve. This valve is used for starting in cold weather, and should be kept open only so long as is absolutely necessary. Both controls should be pushed all of the way in, as soon as the operation of the engine will permit, and all driving should be done with the controls in this position.

28. An air shutter *a'*, Fig. 7 (*a*), is provided so that the temperature of the air entering the carbureter can be varied during different seasons of the year. In the warm months, the shutter should be kept open, while in cold weather a more economical mixture is obtained by keeping the shutter closed, thus admitting warm air only to the carbureter.

Should it be found necessary to change the position of the float *b*, as, for instance, after overhauling the carbureter, it

should be reset, so that, with the motor not running, its top is just even with the bottom of the hole in which the plug c' is inserted. If it is above or below this level, the cap d' should be removed and the locknut e' loosened. Then the needle-valve sleeve f' should be kept from turning by placing a small wrench on its flat sides, and the needle valve g' is screwed up or down, as required, to bring the top of the float level with the bottom of the hole in the side of the gasoline chamber.

STROMBERG CARBURETERS WITH AUXILIARY AIR VALVE

MODELS H, HA, AND HB CARBURETERS

29. General Features.—The models H, HA, HB, K, and KO Stromberg carbureters all employ an auxiliary air valve. The models H, HA, and HB carbureters operate on the same principle and their method of adjustment is identical; the models H and HB are not water-jacketed and differ from each other in that the model H is vertical and the model HB horizontal. The model HA is water-jacketed. All three models have an auxiliary air valve controlled by a dashpot to prevent fluttering, and have the auxiliary air valve interconnected to a metering pin governing the opening of a high-speed gasoline nozzle

30. Model H Stromberg Carbureter.—A model H Stromberg carbureter is shown in longitudinal section in Fig. 8. The gasoline enters at a, passing to the glass float chamber b containing the hollow brass float c and needle valve d for maintaining a constant gasoline level. The main air inlet e is fitted with a strangling valve f, and connects with the Venturi tube g, in the center of which is placed the primary gasoline nozzle h, the discharge of which is controlled by the needle valve i.

The auxiliary air valve j has a hollow stem terminating in a piston k fitting loosely in the dashpot l, which is filled with gasoline; the dashpot and piston prevent fluttering of the air valve. Several small holes are drilled through the hollow stem

of the air valve *j* directly above the piston *k*, and some distance above the gasoline level there is a valve seat *m* which receives the tapered high-speed needle valve *n*. This needle valve has a cap *o* at its upper end, which limits the distance through which the valve *n* can drop, by coming into contact with the upper surface of the high-speed adjusting nut *p*. Gasoline drawn past the high-speed needle valve *n* passes up the hollow stem of the air valve and out through the passage *q* of the air valve into the mixing chamber *r* of the carbureter. The throttle valve is shown at *s*. The downward

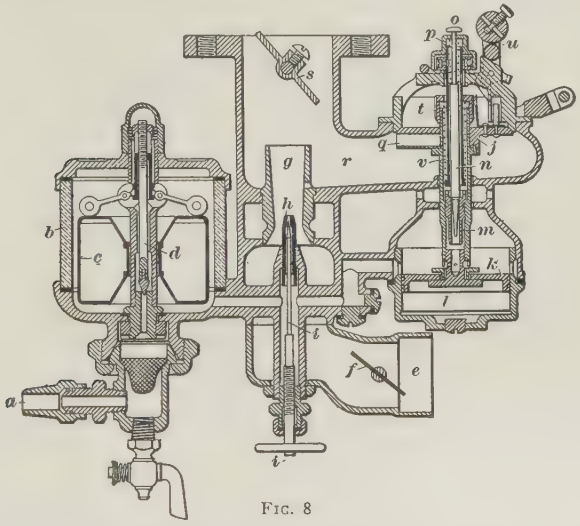


FIG. 8

motion of the air valve *j* is resisted by a helical spring, the tension of which is permanently adjusted at the factory by means of the cap nut *t*.

A rich mixture for starting is given by the bell-crank *u* connected to a dash control; when this control is pulled out, the bell-crank raises the adjusting nut *p*, the high-speed needle valve *n*, and the air-valve-spring seat *v*, thereby giving a large gasoline opening through the valve seat *m* and at the same time increasing the tension of the auxiliary-air-valve spring. The mixture can be still further enriched by closing the strangling valve *f* by means of a separate dash control.

Up to car speeds of 20 to 25 miles per hour on high gear, only the primary nozzle *h* is in action; at higher speeds the high-speed needle valve admits an additional and increasing amount of gasoline.

31. Adjustment of Models H, HA, and HB Carbureters. The models H, HA, and HB Stromberg carbureters are adjusted as follows: The engine having been started and allowed to run long enough to warm up thoroughly, and the two dash controls having been set to *Lean,* the throttle is closed until the engine idles. If it rolls the mixture is too rich and must be made leaner by screwing up on the needle valve *i,* Fig. 8; if the mixture is too lean, the engine will stop when throttled down to idling speed, and must be enriched by screwing down slightly on the valve *i.* The idling speed can be adjusted by the usual throttle-arm stop-screw, which cannot be seen in Fig. 8.

Before attempting the high-speed adjustment, the high-speed adjusting nut *p* should be turned up or down, with the engine stopped, until there is at least $\frac{1}{32}$ inch clearance between its top and the cap *o.* Then, after the low-speed adjustment has been completed, the spark is advanced and the throttle opened. If the engine does not back-fire into the carbureter, the high-speed adjusting nut *p* is turned down, a notch at a time, until the engine does this, and is then turned back until back-firing ceases. If the engine does not respond promptly to the opening of the throttle, it shows the mixture to be slightly weak, and both the low-speed and high-speed adjustments should be set for a slightly richer mixture.

MODELS K AND KO CARBURETERS

32. General Features.—The models K and KO Stromberg carbureters have a single air inlet from which heated air is supplied to the Venturi tube and also to the air valve; a model K carbureter is shown in section in Fig. 9. The fuel enters the float chamber *a,* in which it is maintained at a constant level by the hollow metal float *b* and the needle valve *c.*

The gasoline spray nozzle *d* is placed central with the float chamber and terminates at the throat of the Venturi tube *e*, which receives its air supply from the single air inlet *f* fitted with a strangling valve *g*. The air valve *h* opens downwards against the resistance of a helical spring *i*; the stem of the air valve *h* carries at its upper end a piston *j* fitting the cylinder *k*. An adjusting nut *l* regulates the tension of the spring *i*. In operation the vacuum in the mixing chamber *m* causes the atmospheric pressure on the top of the piston *j* to force this, and hence the air valve *h*, downwards until the downward force

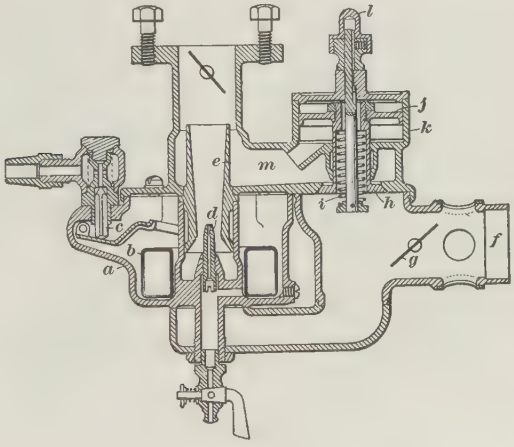


FIG. 9

is equal to the spring resistance; consequently, the opening of the air valve is always proportional to the vacuum in the mixing chamber.

33. Adjustments.—If the Stromberg models K and KO carbureters are completely out of adjustment, an adjustment sufficiently close for starting is obtained by turning the adjusting nut *l*, Fig 9, counter-clockwise, a notch at a time, until on pulling up on the adjusting nut, a decided click, caused by the air valve *h* striking its seat, is heard. The adjusting nut *l* is then turned clockwise, a notch at a time, and pulled up each time, until the clicking sound has just disappeared; the adjust-

ing nut is next turned two notches more. The engine is now started, using the strangling valve to get a rich starting mixture, and when thoroughly warmed up the throttle is closed and the adjusting nut turned a notch at a time one way or the other until the engine runs smoothly. The idling speed is now adjusted by means of the usual throttle-arm stop-screw. It is well to remember that turning the adjusting nut *l* down, or clockwise, enriches the mixture, and turning it up, or counter-clockwise, weakens the mixture.

The gasoline spray nozzle of correct size is usually fitted at the factory, the nozzle being numbered according to the number of the drill with which it was drilled. The nozzle opening gets larger as the number gets smaller, and vice versa. Should the mixture at very high engine speeds be too weak, as evidenced by backfiring into the carbureter, a nozzle one size larger should be substituted; should the mixture be too rich, as shown by the engine choking, a smaller nozzle may be substituted and tried out. After a change of nozzles the carbureter may have to be readjusted.

KINGSTON CARBURETERS

KINGSTON SINGLE AIR-INLET CARBURETER

34. Construction and Operation.—The model L2 Kingston carbureter, built by Byrne, Kingston & Company, Kokomo, Indiana, has a single air inlet and a single air valve, and therefore differs widely from other models built by that company.

Two views of the model L2 carbureter, used on many Ford automobiles, are shown in Fig. 10, in which view (*a*) is an end view, partly broken away, and view (*b*) a longitudinal section. As shown in view (*a*), the gasoline enters the float chamber *a* through the pipe *b* and past the needle valve *c*, which, as the gasoline level rises, is pressed against its seat by a small lever, acted on by the float *d*. The flow of superheated air through the single air inlet is regulated by the choke valve *e*.

The air passes into a V-shaped Venturi tube *b*, which is closed by the flap valve *g*, hinged at *h*. The movement of this valve is not entirely limited by the stop *i*, as the latter will give to a certain extent when the valve is pressing against it.

35. The gasoline nozzle *j*, Fig. 10 (*b*), is controlled by the gasoline-adjusting valve *k*, which extends through the center of the low-speed air tube *l*. The upper end of the nozzle *j* is slightly below the gasoline level when the engine is running; a second nozzle *m*, open to the atmosphere at the bottom, terminates slightly above the regular gasoline

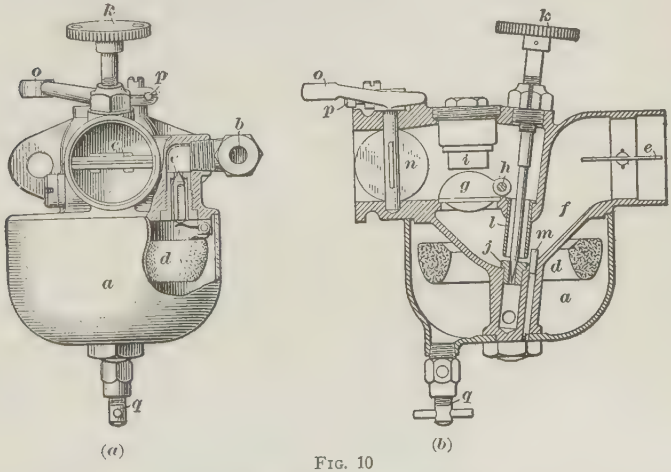


FIG. 10

level, maintained by the float feed apparatus, when the engine is not running. The nozzle *m* serves simply as an overflow to prevent an excessively high gasoline level in the bottom of the Venturi tube *f*; it has no influence on the operation of the carbureter. The carbureter throttle *n* is of the butterfly type; the throttle arm *o* is fitted with the usual stop-screw *p* for regulating the idling speed of the engine. A drain cock *q* is provided for emptying the float chamber.

36. The operation of the carbureter shown in Fig. 10 is as follows: With the engine at rest, a puddle of gasoline lies at the bottom of the Venturi tube *f*, sealing the

lower end of the low-speed air tube *l*; the air-flap valve *g* rests on its seat. On cranking the engine, the liquid gasoline in the bottom of the low-speed air tube *l* is drawn up through the tube until its bottom is uncovered. Then air enters the tube and on mixing with the gasoline forms a very rich mixture for easy starting. As soon as the engine fires and while running at low speed, all the combustible mixture passes through the low-speed air tube *l*, the air entering the mouth of the air tube sweeping over the mouth of the nozzle *j*, and picking up sufficient gasoline. When the engine is speeded up, the air valve *g* lifts off its seat and a combustible mixture now passes to the engine both through the low-speed air tube *l* and though the opening between the air valve *g* and its seat. The air valve *g* rises more with every increase of engine speed, thus permitting more air to pass through the Venturi tube *f* with an increasing velocity, thereby picking up enough gasoline from the nozzle *j* to maintain a practically constant ratio of gasoline to air at all engine speeds.

37. Adjustment.—The only adjustment of the carbureter is that of the gasoline by the valve *k*, Fig. 10; care should be taken to loosen the locknut on the valve before making the adjustment, and to tighten the locknut when the adjustment is completed. If the carbureter is completely out of adjustment, the needle valve *k* is turned to the right until it seats lightly, and then to the left one complete revolution. The engine is then started and allowed to run until completely warmed up. Next, the idling speed is adjusted by closing the throttle and adjusting the throttle stop-screw. With the engine idling, the valve *k* is turned to the right, a little at a time, until the engine slows down, thus indicating a weak mixture; the valve *k* is then turned to the left again very slowly until the engine runs strong. If upon opening the throttle quickly the engine does not respond immediately, it indicates a slightly weak mixture, and the valve *k* must be turned a little more to the left.

KINGSTON CARBURETER WITH MULTIPLE AIR VALVES

38. Construction and Operation.—A modified form of the Kingston carbureter is shown in Fig. 11, which is known as the *model E*. In this illustration (*a*) is a plan view and

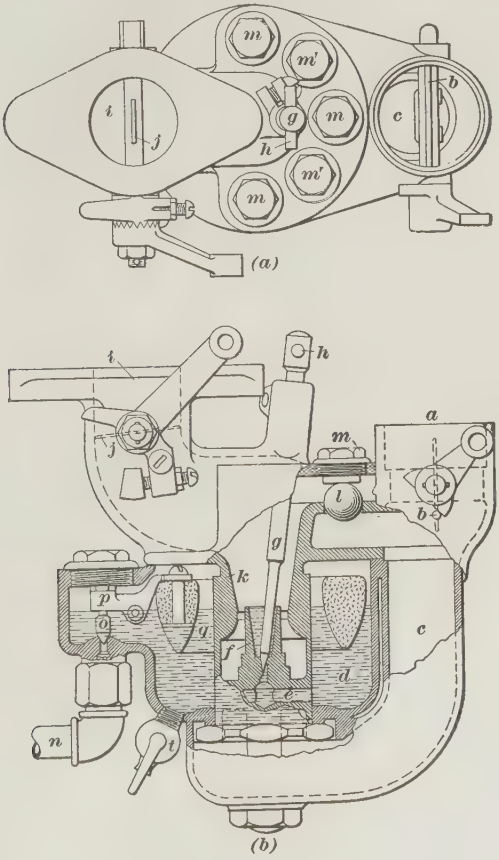


FIG. 11

(*b*) a side view. In the latter view portions of the walls of the float chamber and of the air-inlet tube are broken away to disclose the interior construction of these parts, which differ somewhat from the corresponding parts of the model L2,

already described. Models L2 and E differ also in so far that the latter, as seen from the illustration, is a vertical carbureter, because the throttle-valve passage is vertical, instead of horizontal, as in Fig. 10. The air enters at *a* and flows past the choke valve *b* down through the tube *c* and below the float chamber, or cup, *d*. The latter is ring-shaped and has in its central opening a cross-pipe *e*, which connects both sides of the chamber. At the center of this pipe is located the gasoline nozzle *f*, which forms a cup around the needle valve *g*, provided at its upper end with a handle *h* by which it may be turned. The gasoline rises in the nozzle *f* until its level is $\frac{1}{32}$ inch below the top.

39. The air coming through the tube *c*, Fig. 11 (*b*), will pass up on both sides of the pipe *e* and into the tube *i* past the throttle valve *j* to the engine. An auxiliary air current is flowing under certain conditions through the circular openings, at present closed by the balls *l*. The upward motion of these balls is limited by the nuts *m* and *m'*, the positions of these nuts, in view (*a*), indicating that the balls are arranged in a semicircle around the Venturi tube *k*, view (*b*). Gasoline flows into the float chamber *d* through the pipe *n*, the supply being regulated in the usual manner by the needle valve *o*, in conjunction with the lever *p* and the float *q*.

40. The operation of the carbureter, Fig. 11, is as follows: When the engine is started, the excess of gasoline contained in the nozzle *f* is drawn up by the current passing up through the Venturi tube *k*. As the engine gains speed the nozzle *f* is emptied and more gasoline is drawn through the needle valve.

Both the constant and the auxiliary air supplies are drawn from a common source, the tube *a*, the air being impregnated with gasoline spray as it passes the nozzle *f*. After passing through the Venturi tube *k*, the air current is joined by an auxiliary air current that flows past the balls *l*, these balls being raised higher and higher, thus allowing an increased amount of air to pass as the engine approaches its normal speed. The amount of air permitted to flow past these balls

depends on the existing vacuum in the mixing chamber above the Venturi tube. The choke throttle *b* is so placed that the air supply may be cut off entirely, thus producing a vacuum in the Venturi tube high enough to enable the engine to start at exceptionally low temperatures.

41. Adjustments.—The following requirements should be complied with in using the Kingston carbureter, Fig. 11: The fuel level in the nozzle *f* should be constant and of the proper height; that is, from $\frac{1}{32}$ to $\frac{1}{16}$ inch below the top of the nozzle. The position of this level may be ascertained by removing the ball caps *m'*, view (*a*), to permit light (not from an open flame) to enter one of the holes; then, on looking through the other hole the position of the level may be seen. Previously the needle valve *g* must have been withdrawn from the nozzle. If the level is found to be too high, the right-hand arm of the lever *p* must be bent down, so that the float *q* will make the valve *o* close the gasoline inlet at an earlier stage. If the level is too low, the right-hand arm of the lever *p* is bent in the opposite direction.

42. Leaky Needle Valve.—If it is found that the needle valve *o*, Fig. 11 (*b*), is leaking, it must be attended to at once. Possibly some dirt may be lodging on its seat, thus preventing the valve from shutting off the supply. The cap *q* should be removed and the float depressed to allow an inrush of fuel that will drive the dirt away from the seat. The excess gasoline in the chamber is then removed by opening the drain cock *t*. If this procedure fails to remove the dirt, the needle valve *o* should be turned back and forth on its seat by means of a screwdriver applied to the upper end of the stem, simultaneously exerting a slight pressure. In case the leakage is caused by an injured or badly worn seat or valve, the valve must be reground while in place. For this purpose the chamber *d* must be removed from the carbureter body and thoroughly washed with gasoline. The valve is then turned back and forth on it with a screwdriver, using on the seat a little oil, but no abrasive.

TILLOTSON CARBURETERS

43. Construction and Operation.—The Tillotson Manufacturing Company, Toledo, Ohio, produces various models of carbureters without air valves, classified as *non-air-valve carbureters*. These may either be vertical or horizontal. A longitudinal section of the vertical type is shown in Fig. 12. In this carbureter there is a minimum number of parts, the body casting being integral with the Venturi tube, the float

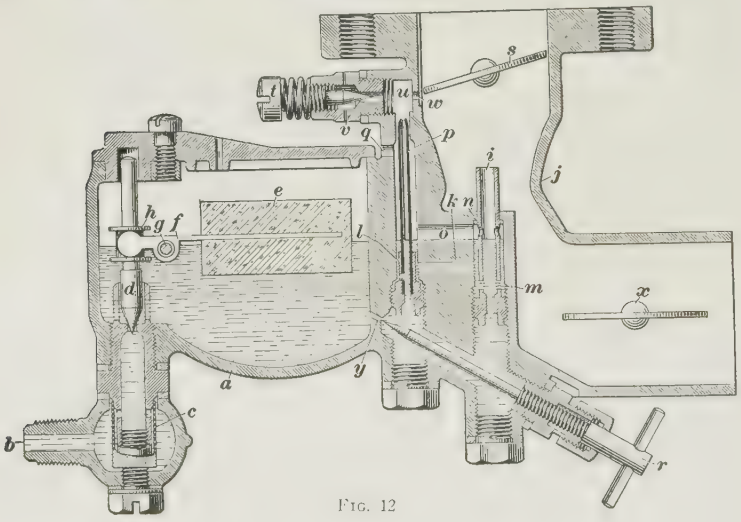


Fig. 12

bowl, and the air-horn elbow. This arrangement makes a carbureter of rugged construction.

There is a single float chamber, a bowl *a*, the gasoline entering at *b* and flowing through the screen *c* past the inlet valve *d* into the bowl. This valve is insured a perfect seating by being guided at the top and bottom, while the weight of the valve is sufficient to regulate the flow of fuel against a considerable head; its downward pressure is reinforced by the pressure exerted indirectly by the float *e*, which is attached to one end of the lever *f*. This lever is pivoted at *g* and has a short forked arm engaging the collar *h*, which is fastened to the

valve stem. The level of the gasoline in the bowl *a* should be $\frac{3}{32}$ inch below the cover of the bowl.

44. The main nozzle *i*, Fig. 12, feeds a mixture of fuel and air into the Venturi tube *j* at a point just above its throat. The bore of the nozzle *i* is contracted near its lower end in order that the fuel may tend to break up when the engine is running at higher speeds. The annular space outside the middle portion of this nozzle, in combination with the cross channel *k* and the lower portion of the well *l*, acts as an acceleration well. The fuel flows into these parts through the holes *m* in the nozzle *i*, the upper holes *n* admitting air, drawn through the cross channel *o* from the well *l*, which surrounds the by-pass tube *p*, and is supplied with air through the large hole *q*. The air that enters the nozzle *i* serves to break up the fuel before it passes into the Venturi tube and thus insures economic running at low speeds. As the engine speed is increasing, the accelerating well is drained of fuel and air is then also drawn from the channel *k* into the nozzle *i*, thus breaking up the fuel also at medium and high speeds. The needle-adjusting screw *r* governs the quantity of fuel supplied to the nozzle *i* and the by-pass tube *p*. An approximately correct position of this screw is $2\frac{1}{2}$ turns off its seat. By turning it to the right the fuel supply is decreased.

45. The idling speed of the engine is adjusted by means of the throttle valve *s*, Fig. 12, in conjunction with the needle valve *t* and the by-pass unit *p*, consisting of a long narrow tube with its lower end pressed into a threaded plug. The upper end of the tube is contracted to limit the flow of fuel. This tube conveys the fuel to the mixing chamber *u*, to which the air is admitted through the holes *v*, the supply being governed by the needle screw *t*. The fuel mixture passes from the chamber *u* through a small hole *w* located near the edge of the throttle valve *s*. When the latter is tightly closed, the upper half of the hole *w* should be covered by the edge of the valve, as shown.

During the idling of the engine the hole *w* is practically closed. As the throttle is opened, a greater area of the hole

will be exposed to the action of the vacuum existing above the throttle and more fuel mixture will therefore be supplied by the by-pass unit p. The hole q reduces the effect of the suction in the well l and prevents the tube p from supplying fuel through the hole w at medium and at high speeds. By arranging to have the by-pass draw its fuel from the same channel as the nozzle i, the by-pass will fail to be supplied when the nozzle begins to draw strongly. These features serve to economize the fuel and thus to secure more miles per gallon.

46. Adjustments.—The various adjustments of the carbureter, Fig. 12, are made in the following manner: The approximate position of the screw t is $\frac{3}{4}$ turn open. On screwing it inwards, the mixture becomes richer. When the throttle valve s is in its closed position, the valve should make an angle of 15° with the horizontal; hence, the throttle lever will travel through an angle of 75° to move the valve into a wide-open position. This lever has a stop-screw which, in conjunction with the valve t, serves to adjust the idling speed of the engine.

In the choker butterfly valve x there is a small hole to allow a limited amount of air to pass through while the valve is shut, thus preventing the fuel from becoming too rich. When the engine is being started, the choker button should be pulled clear out and the throttle lever set in a position corresponding to a speed of 15 to 20 miles per hour. The starter button should then be stepped on, and as soon as the engine begins to fire, the choker button should be worked in and out until the engine begins to run smoothly. After the engine warms up, the choker button is gradually pushed in, about $\frac{1}{8}$ inch at a time, until the engine is warm throughout, when the button is pushed in entirely.

47. Before beginning to adjust the carbureter, Fig. 12, the spark plugs and the contact-breaker points should be examined to see that they are correctly set, so that when the spark is fully retarded the flywheel will not have to make more than $\frac{1}{8}$ revolution before it reaches its dead-center position. The needle valve r is then turned out $2\frac{1}{2}$ revolutions from its

closed position, and the screw *t* is opened $\frac{3}{4}$ turn. The valve *r* should be so adjusted that when the spark is fully retarded the throttle can be opened wide without having the engine back-fire into the carbureter. Then the screw *t* is adjusted to give the correct mixture at the desired idling speed.

If the idling speed is to be reduced, the throttle-stop clamp screw should be loosened and the stop-screw turned to the left, thus permitting the throttle valve to move toward its closing position. In making this adjustment it is sometimes necessary to readjust the screw *t*. When, during the adjustment of the carbureter, it is found impossible to accelerate with a retarded spark without having the engine back-fire into the carbureter, even with the valve *r* wide open and the ignition correctly timed, the cause may be one of the following: The fuel level in the bowl is too low; or the hole *y* or one of the channels *k* and *o* is stopped up.

48. The adjustments of the carbureter, Fig. 12, made in the manner described, will give it a maximum efficiency. Sometimes a slight increase in efficiency may be secured by readjusting the valve *r* so as to reduce the opening at *y*. In order that the best results may be obtained from this and other carbureters, it is essential that the carbureter shall receive regular attention and be kept clean both externally and internally. The screen *c* should be freed from any solid particles, and every effort made to keep water away from the gasoline and the interior of the carbureter.

As there is considerable difference in the fluidity of the various fuels found in the market, it is desirable that the same kind of fuel should be used whenever possible, so as to eliminate the necessity of having to readjust the carbureter.

EAGLE CARBURETERS

49. Construction and Operation.—The Eagle Carbureter Company, successor to the K. D. Carbureter Company, manufactures the Eagle carbureter, which has been used in some models of the Maxwell car. The greatest part of this carbureter is shown in longitudinal section in Fig. 13. The mixing

chamber *a*, which is located at one side of the float chamber *b*, contains the ball air valve *c*. By means of the adjusting screw *d*, the position at which the ball comes to rest in the air intake *e*, may be varied. An adjustable needle-valve *f* is provided in the spray nozzle *g*, but this valve is used only for permanent adjustment and is not controlled from the dash, as was the case in the K. D. carbureter.

50. Gasoline enters the carbureter at *h*, Fig. 13, passes through the screen *i* and the valve *j* to the mixing chamber *b*.

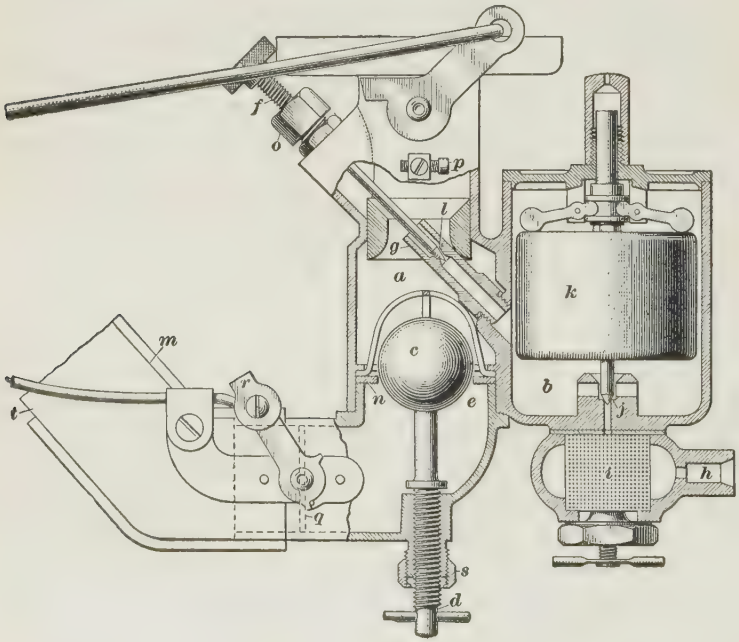


Fig. 13

The float *k* maintains a gasoline level in the float chamber slightly higher than the opening *l* of the spray nozzle. The air entering the carbureter by way of the hot-air pipe *m* and the air intake *e* is controlled by the ball *c*. At low engine speed the suction is not sufficient to raise the ball very far off its seat *n*; but, as the engine speed increases, the ball rises higher,

and more and more air enters the mixing chamber. The greater velocity of the entering air at the higher speeds causes more gasoline to be drawn from the spray nozzle, the mixture thus automatically adjusting itself to the requirements of the different engine speeds.

51. Adjustments.—The high-speed adjustment of the Eagle carbureter, Fig. 13, is made in the following manner: If the carbureter is badly out of adjustment, the locknut *o* should be loosened, and the needle valve *f* turned to the right until it seats lightly, after which it should be turned to the left about three-quarters of a turn. The throttle stop-screw *p* should be set to approximately the correct position for idling, the choke valve *q* closed by pulling out on the dash choke lever *r* and the engine started. As soon as the engine starts, the choke lever should be pushed all the way in, and the engine allowed to run until it has warmed up, the proper idling speed being obtained by adjusting the throttle stop-screw. The spark lever is then placed in the fully retarded position, and the throttle is opened to give an average driving speed.

The needle valve *f* is next turned to the right, a little at a time, until the engine speed slows down, due to a lean mixture Then the needle valve is turned to the left until the engine first speeds up and then begins to slow down again. By turning the needle valve to the right once more until the point is reached at which the engine speed is the highest, the correct mixture for general driving is obtained. The locknut *o* should then be retightened, care being taken not to turn the needle valve while doing so.

52. The air-adjusting screw *d*, Fig. 13, is provided to control the air supply to the carbureter at low engine speeds. If the engine does not run evenly at low speeds, it is probably because the gasoline adjustment at the needle valve gives a mixture that is slightly too rich for idling purposes, and causes the carbureter to choke. The locknut *s* should be loosened, the air screw *d* turned to the right until the engine runs evenly at low speed; then, on tightening the locknut, the adjustment is completed.

Any adjustments required for summer or winter driving should be made at the needle valve *f* in conjunction with the shutter *t* in the air inlet. A slightly richer mixture necessary when driving in cold weather can be obtained by giving the needle valve *f* a slight turn to the left. The shutter *t* should be kept in the closed position during cold weather, and opened, if necessary, in the warmer weather.

SCOE CARBURETERS

53. Construction.—The Scoe carbureter, manufactured by the Briscoe Devices Corporation, Pontiac, Michigan, has a single air valve, or shutter, so connected with the metering pin that the richness of the mixture is automatically varied to suit the different speed and load requirements.

A cross-sectional view of the carbureter is shown in Fig. 14 (*a*), while separate views of the air shutter and the metering pin are shown in (*b*) and (*c*), respectively. The air shutter *a*, the shape of which is shown more clearly in the perspective bottom view in (*b*), is hinged at *b* to the body of the carbureter and is connected at the other end to a metering pin *c*, which is free to move up and down in its guide *d*. The metering pin carries two distinct jets, shown clearly in view (*c*). The central jet *e*, which connects with the channel *f* in the piston stem, is fed by two holes *g* and *h*, the lower hole *h* being the smaller. The second jet is formed by the space between a flat surface *i* milled on the front side of the metering-pin stem, and the guide *d* in which the metering pin operates. The flat surface begins about $\frac{1}{16}$ inch below the bottom of the head *j*, and its depth remains constant for a distance of about $\frac{7}{16}$ inch, from which point it increases in a uniform taper. The Venturi tube of the mixing chamber is formed by the space between the air shutter *a* and the floor of the carbureter. As the air shutter rises, the size of this tube is increased, thus approximating a constantly increasing ratio of air to gasoline

54. The float chamber *k*, Fig. 14 (*a*), surrounds the metering pin *c*, the guide *d* being hollowed out at the bottom to form

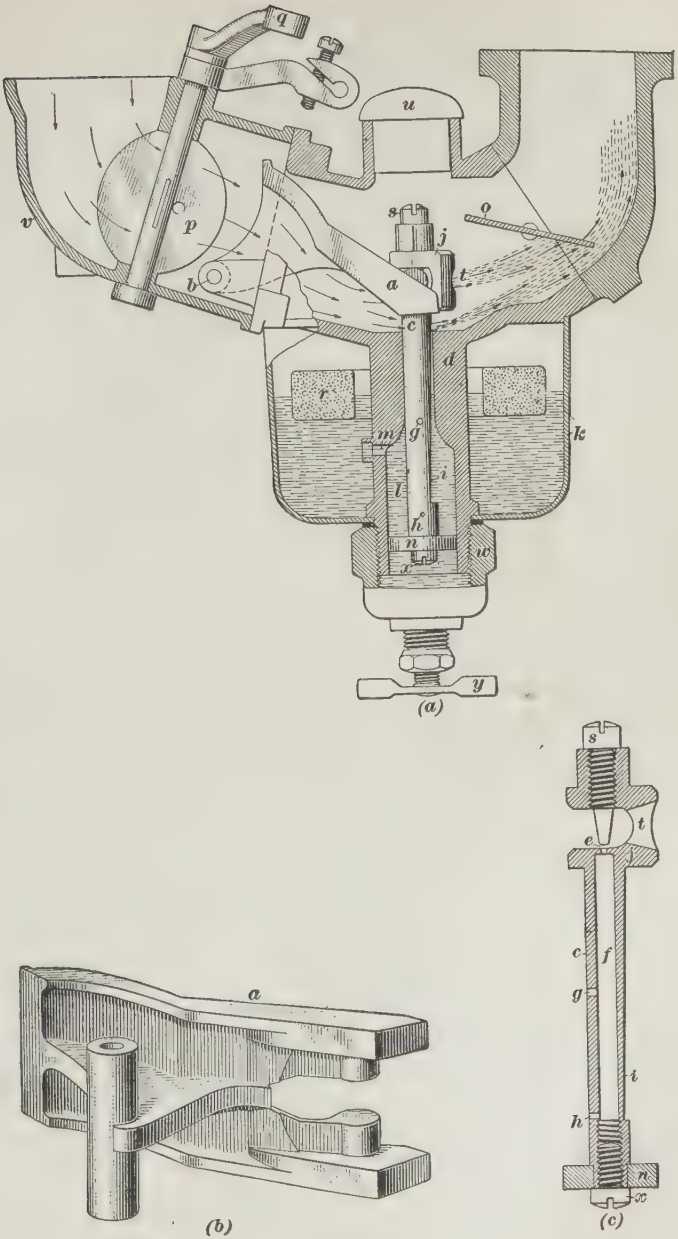


FIG. 14

the gasoline well *l*. Gasoline enters this well from the float chamber by way of the opening *m*. The bottom of the metering pin *c* carries a piston *n* which fits loosely in the well *l*, thus forming a dashpot that steadies the up-and-down motion of the metering pin, and prevents sudden fluctuations in the gasoline mixture The throttle valve is shown at *o*, the choke valve at *p*, and the choke-control lever at *q*. The laminated cork float *r* carries a needle valve, not visible in this view, that controls the height of the gasoline in the float chamber.

55. Operation.—The operation of the Scoe carbureter, Fig. 14, is as follows: When the engine is idling, or when the car is running at low speed, say 8 miles per hour, under normal conditions, the air drawn through the carbureter is not sufficient to raise the air shutter *a*. Consequently the metering pin *c* is not raised, and the gasoline feed is almost entirely through the central jet *e*. As both the holes *g* and *h* are supplying gasoline to the inside of the metering pin, the discharge from the jet *e* is restricted only by the setting of the adjusting screw *s*. This screw, which is flat at the end, serves to atomize the column of gasoline coming from the jet *e* and at the same time keeps the mixture from becoming too rich as the air speed through the opening *t* increases. When the car speeds up to about 16 miles per hour, or is running under heavy load at 5 to 8 miles per hour, the force of the air passing through the carbureter is sufficient to raise the air shutter *a* from $\frac{1}{16}$ to $\frac{5}{32}$ inch. The flat jet *i* cuts in at a $\frac{1}{16}$-inch rise of the metering pin, and supplies the gasoline necessary to meet the requirements for a richer mixture

56. As the car speed is increased still further, for instance, to between 18 and 35 miles per hour, or 8 to 18 miles per hour under load, the air shutter *a*, Fig 14 (*a*) and (*b*), in rising, raises the metering pin *c* to a point where the upper hole *g* in the metering pin is closed by entering the contracted portion of the well *l*. The discharge from the central jet *e* is now restricted to the fuel admitted by the lower feed hole *h*, which is much smaller than the upper one, and the quantity of fuel in the mixture is reduced, even though the air

opening is increased by the raising of the air shutter *a*. This gives a lean driving mixture, which is very desirable at the speeds mentioned, because it is at this range that most of the driving is done. The flat jet *i*, views (*a*) and (*c*), remains constant throughout the movement of the metering pin, as the pin is not raised over $\frac{7}{16}$ inch at this stage.

At speeds between 35 and 55 miles per hour under normal driving conditions, the metering pin is raised to a height between $\frac{7}{16}$ and $\frac{7}{8}$ inch, according to the speed. The central jet *e* continues its restricted flow because the upper feed hole *g* is still covered, but the depth of the flat jet *i* has increased somewhat because of the slight taper, giving a mixture suitable for the wider air-shutter opening.

57. Adjustment and Cleaning.—After the carbureter, Fig. 14, is set at the factory, there is little likelihood of the need of further adjustment. If any adjustment is necessary, the idling mixture may be regulated by removing the cap *u*, view (*a*), from the top of the carbureter, and turning the screw slightly. Turning this screw to the right weakens the mixture, and to the left enriches it. No attempt should be made to adjust the carbureter at the screw *s* for other than low or idling speeds, because the effect of this screw becomes negligible at speeds wherein the upper feed hole *g* of the metering pin becomes inoperative.

The metering pin may be taken out for cleaning by removing the hot-air stove, which is usually employed with the Scoe carbureter, as well as the choke-valve body *v*, the cap *u*, and the nut *w*. While holding down the metering pin from above, the screw *x* should be removed, which releases the piston *n* and permits the metering pin to be lifted out. The float chamber may be drained by opening the drain cock *y*, or it may be removed entirely for cleaning, by unscrewing the nut *w*.

HUDSON AND ESSEX CARBURETERS

58. Construction and Operation.—A special carbureter of the single air-inlet type, with the size of the air inlet automatically varied to suit the throttle opening, was until recently used in the Hudson cars built by the Hudson Motor Car Company, Detroit, Michigan. This carbureter is shown in Fig. 15 (*a*)

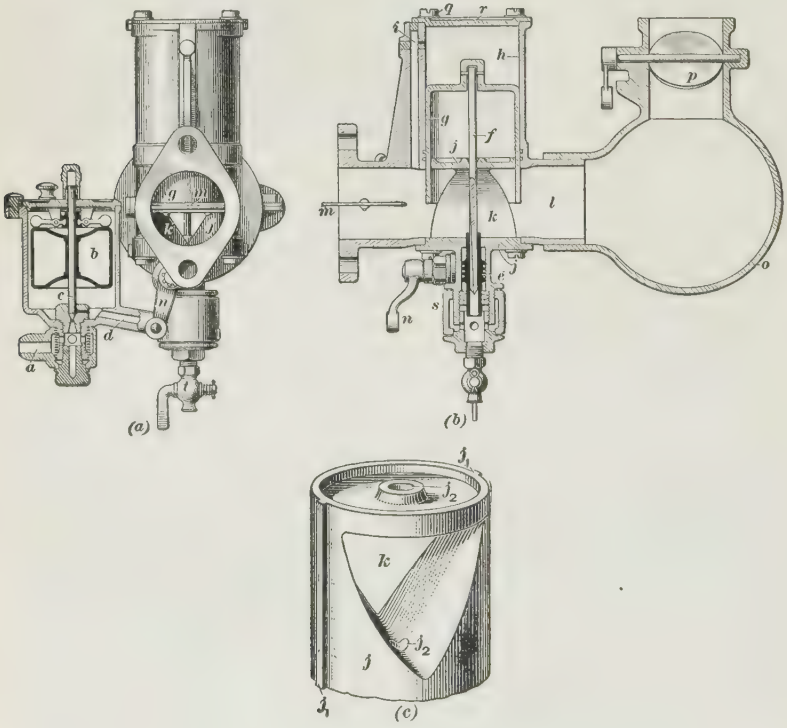


FIG. 15

in an end view in which the float chamber is shown in section. In view (*b*) is shown a longitudinal section of the carbureter and intake. The gasoline inlet is at *a*, view (*a*), whence the gasoline passes into the float chamber, which contains a metallic float *b* and a needle valve *c* for maintaining a constant level. The gasoline passes through the passage *d* to

the cylindrical spray nozzle e, view (b), called in the carbureter the *gasoline feed regulator,* in which works a metering pin f, free to slide in it. This metering pin has a tapering **V** groove cut in it lengthwise and facing the engine, the groove being widest at the bottom. The purpose of this groove is to vary the amount of gasoline that passes by the metering pin into the mixing chamber. Obviously, the size of the gasoline opening is greatest when the metering pin is raised to the limit.

59. The metering pin f, Fig. 15 (b), is fastened at its upper end to a piston g free to slide vertically in an air chamber h, which communicates by means of the passage i with the engine side of the mixing chamber. The piston g fits loosely over a cylindrical guide j, which has a large **V**-shaped opening k cut through it in line with the mixing chamber; the opening k is widest at the top.

The construction of the guide j is shown more clearly in view (c), which is a perspective view of its upper part, the lower flange and cylindrical extension being broken away. The ribs j_1 fit into corresponding slots cut in the piston g to prevent it from turning. The metering pin passes through the holes j_2. Therefore, the position of the piston g determines the area of the passage through the opening k for the admittance of air from the inlet l. The throttle valve is shown at m.

The position of the nozzle e with reference to the metering pin f can be changed by means of the feed-regulator lever n, which operates a pinion meshing with rack teeth cut into the feed regulator e. Raising the feed regulator e by hand by means of the dash control weakens the mixture, and dropping the regulator enriches the mixture, over the whole range of engine speed in either case.

60. The 1923 Hudson carbureter and the Essex four carbureter differ from the one shown in Fig. 15 only in the method of applying them to the engine, the hollow ball-shaped intake o being supplanted by a bell-shaped device, the base of which is turned toward the carbureter.

61. Starting the Engine.—The handling of the Hudson carbureter, Fig. 15, while starting the engine, is as follows:

To start the engine, the feed regulator *e* is dropped by means of the dash control, and the choke valve *p* is closed by the choke lever on the dash to enrich the mixture for starting. As soon as the engine fires, the regulator is brought back to give a weaker mixture, and the choke is released. Owing to the partial vacuum in the mixing chamber and in the cylinder *h* in which the piston *g* works, the piston rises to a height corresponding to the throttle opening, thereby enlarging the air opening *k* when the throttle is opened, and decreasing it when the throttle is closed. By this means a practically constant vacuum is maintained at the gasoline feed-regulator opening, and, in conjunction with the tapered groove in the metering pin, a constant ratio of gasoline to air is maintained.

62. Adjustments.—The only adjustment of the Hudson and the Essex carbureter is that obtainable by raising or lowering the gasoline feed regulator *e*, Fig. 15 (*b*), by means of the dash control. It is necessary, however, that the carbureter be periodically inspected, if maximum performance and economy are to be maintained. As the piston *g* automatically regulates the air supply to conform to different throttle openings, any sticking of the piston will seriously interfere with the action of the carbureter. In order that it shall work freely at all times, it should be removed occasionally and polished.

The piston and metering-pin assembly can be lifted out after the four screws *q* and the cover *r* have been removed. The surface of the piston should be carefully cleaned and polished with metal polish, care being taken not to scratch or dent it. The walls of the cylinder in which the piston operates should be similarly treated. Under no circumstances should any abrasive such as sandpaper or emery cloth be used when cleaning the piston.

When returning the piston to its place in the cylinder, it should be turned so that the groove in the metering pin faces the engine. The arrow on the top of the piston will serve as a guide in locating it properly. If this position is reversed, the carbureter will fail to operate. The cover *r* should be drawn down air-tight by means of the screws *q*.

63. The packing gland *s*, Fig. 15 (*b*), may need tightening or repacking occasionally. When this gland is not fitted tightly on the regulating sleeve, gasoline will enter the engine also by way of the outside of the sleeve instead of being solely regulated by the metering pin *f*, and while the loose gland will not be revealed by a leakage from the carbureter, the gasoline mileage will be low, and trouble will be experienced through undue crank-case oil dilution, fouled spark plugs, etc.

To tighten or repack the packing gland, it is best to remove the carbureter from the engine, although the repacking may be done with the carbureter in place. In that case the petcock *t* and the float chamber must first be removed. A special wrench is then used for packing the gland. The gland nut should be screwed in far enough to cause the regulator lever *n* to offer resistance to turning. For repacking the gland soft candle wicking should be used.

If the special wrench is not available, a broad screwdriver may be used for adjusting the gland; but, generally, this requires the removal of the carbureter. The use of the proper wrench is recommended, because with it the sleeve can be raised or lowered during the tightening process, thereby assisting in obtaining the desired adjustment. Before reassembling the float chamber and the carbureter body, the inlet screen should be carefully examined to see that it is perfectly clean.

STEWART CARBURETERS

CARBURETERS USED ON DODGE BROTHERS CARS

64. Construction.—A number of different models of single and duplex Stewart carbureters, in horizontal and vertical patterns, are manufactured by the Detroit Lubricator Company, Detroit, Michigan; all of them embody the same principle of operation, although differing in details of construction. All single Stewart carbureters have a single air inlet and a single weighted air valve through which all the air is admitted; in the duplex carbureter each mixing chamber has its own air inlet and air valve.

65. In Fig. 16 is shown the single Stewart, model 25, carbureter used in the Dodge Brothers car, which carbureter is of the horizontal pattern, bolting directly to the cylinder casting. The float chamber contains a metal float and the usual gasoline needle valve for maintaining a gasoline level. The air valve, called the *automatic metering valve* by the manufacturer, consists of several parts firmly united so that they move as one piece. These are: The valve stem *a*, which is enlarged at the bottom to form the dashpot piston *b*; the lower head *c* resting on top of the valve stem *a* and secured to it by the upper head *d*; and the aspirating tube *e* which serves as a spray nozzle.

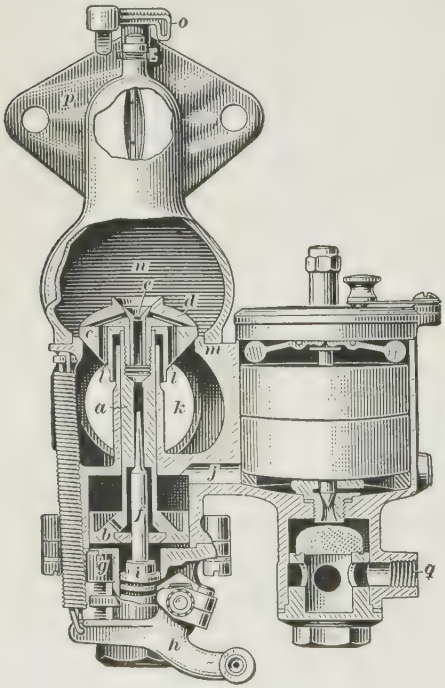


FIG. 16

The metering pin *f*, used for obtaining a rich mixture temporarily for starting, is operated by means of a dash control. The position of this pin, relative to the automatic air valve, is adjusted by means of the thumb-screw *g*, which controls the lever *h*, connected to a pinion that meshes with the circular rack *i* on the metering-pin carrier.

The float chamber communicates with the dashpot and the central hole of the valve stem *a* by the passage *j* so that gasoline rises in the annular space between the tapered part of the metering valve *f* and the central hole in the valve stem to the same height as in the float chamber. The air inlet to the carbureter is shown at *k*; the primary air passages *l* are drilled into the lower and upper heads *c* and *d* of the metering valve

and lead to the conical hole or combining tube at the top of the upper head *d*. The upper end of the aspirating tube *e* is flared out and terminates at the throat of the conical hole of the upper head. With the engine at rest or idling, the metering valve is down and the lower head *c* is resting on the circular seat *m*; hence air from the inlet *k* can enter the mixing chamber *n* only by way of the passages *l*.

The throttle valve is of the butterfly type and is operated by the lever *o*; the flange *p* is used for bolting the carbureter to the cylinder block. The gasoline inlet for the carbureter is at *q*. The dashpot piston *b* is a loose fit in its chamber, and this slight clearance allows the gasoline to flow past the piston into the space beneath.

66. Operation.—The operation of the Stewart carbureter is as follows: To start the engine, especially when cold, a rich mixture is needed, which is supplied by operating the dash control so as to lower the metering pin *f*, Fig. 16, thereby enlarging the gasoline inlet opening to the aspirating tube *e*. The vacuum formed in the mixing chamber *n* by the cranking of the engine causes air to rush at high speed through the passages *l*, meeting the gasoline coming from the flared upper end of the aspirating tube *e* and atomizing and vaporizing it, thereby producing a combustible mixture. As soon as the engine fires, the dash control is operated to raise the metering pin to its normal position, giving the proper idling mixture; as long as the engine idles, the automatic valve remains seated on the seat *m*. On opening the throttle the automatic metering valve rises to a height depending upon the throttle opening and engine speed, and air then rushes into the mixture chamber *n* past the seat *m*. As the tapered metering pin *f* has not moved with the valve, it follows that the opening for gasoline is increased. Thus, the motion of the metering valve relative to the stationary pin *f* will serve to maintain a constant ratio of gasoline to air over the whole range of the engine speed above that of idling. The entire air supply for the carbureter enters through the single air inlet *k* and is preheated by being passed over the exhaust pipe of the engine.

67. Adjustment.—There is only a single adjustment on Stewart carbureters, and this need not be changed after it has once been set. This adjustment is made by the screw *g*, which forms an abutment limiting the upward travel of the metering pin by limiting the movement of the lever *h*, Fig. 16. By turning this screw to the right, the mixture is enriched, and by turning it to the left the mixture is made weaker over the whole range of the engine. No change in adjustment should be made until the engine is thoroughly warmed up and the dash control is operated to give the highest metering-pin position. Then, if the engine back-fires into the carbureter when speeded up, the adjusting screw is turned to the right, a very little at a time, until back-firing ceases. Conversely, if the engine does not back-fire, the adjusting screw is turned to the left until it does, and then to the right again until back-firing ceases.

CARBURETERS USED ON HUDSON, ESSEX, AND MAXWELL CARS

68. Construction.—Another form of the Stewart carbureter is used on the Hudson, Essex, and Maxwell cars. In construction the Maxwell carbureter differs slightly from that used in the Hudson and the Essex, but its operation and adjustment are practically the same. The carbureter shown in the cross-section, Fig. 17, is used on the Hudson and the Essex cars. It is of the vertical pattern and is provided with a flange *a*, bolting directly to the cylinder casting. The general construction of the parts corresponds very closely with that found in the Dodge Brothers model, Fig. 16, excepting the construction of the metering valve.

In the model shown in Fig. 17, the valve head *b* is in one piece, which replaces the two pieces provided with separate channels, as in Fig. 16. The channels *c*, Fig. 17, point directly to the enlarged end of the aspirating tube *d*, thus avoiding the sharp corners found in the other design. Some changes will be found also at the lower end of the metering valve unit; thus, there are two gasoline passages *e*, leading directly to the annular space *f*, surrounding the metering pin *g*.

69. On the shaft *h*, Fig. 17, is keyed a pinion *i*, which engages a cylindrical rack *j* for the purpose of raising or lowering the metering pin *g*, a helical spring *k* inserted below the rack, serving to force the latter upwards and thus stop the fuel supply. To the shaft *h* is also attached the dash adjustment lever *l* by means of which the pinion *i* may be turned so as to lower the metering pin and thus permit gasoline to flow into the tube *d*. When released by the dash control, the position in which the lever *l* comes to rest is determined by the position of the adjustment screw *m*.

The fuel-supply connection *n* is cast integrally with the float chamber *o*, the fuel passing from the supply pipe through the hemispherical strainer *p* and the needle valve *q* into the float chamber. As the remaining parts are identical with those shown in Fig. 16, they need not be described.

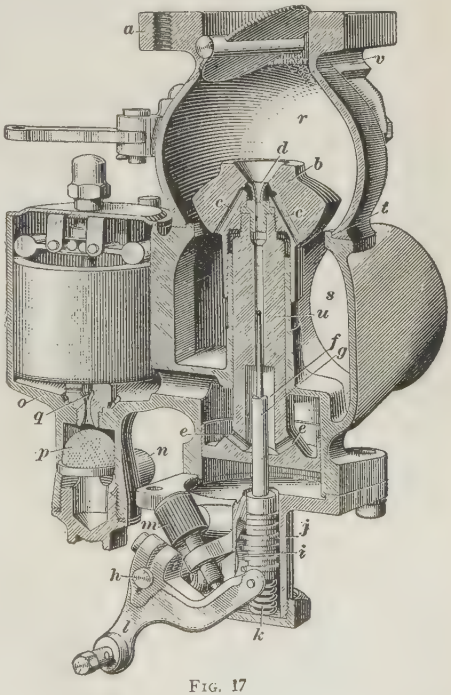


FIG. 17

70. Operation. The action of the carbureter, Fig. 17, is as follows: The vacuum created in the mixing chamber *r* by the downward stroke of the engine piston draws air through the primary openings *c*. The existing vacuum draws also a fine spray of atomized fuel from the nozzle *d* into the mixing chamber.

As soon as the engine begins to operate, the valve *b* lifts sufficiently high to allow a current of air to enter the opening *s*

and pass between the head *b* and its seat *t*. The fuel is metered by the tapering end of the stationary pin *g*. As the metering valve is lifted into a higher position, more fuel is passing this pin and more air flows past the seat *t*; hence, the valve operates under all conditions automatically in measuring and delivering to the mixing chamber the most efficient mixture of fuel and air.

71. Adjustments.—The only adjustment possible in the carbureter, Fig. 17, is that which changes the position of the pin *g* relative to the lower end of the opening *d* in the valve stem *u*. This adjustment is effected by turning the screw *m* in the required direction. By turning the screw to the right, the lever *l* with its shaft *h* and pinion *i* is turned clockwise and the rack *j* and the needle *g* are lowered, thereby increasing the annular fuel opening around the pin *g* and obtaining a richer mixture. By turning the screw in the opposite direction, the mixture becomes leaner.

In making this adjustment the best results are obtained by first letting the engine run a sufficient length of time to permit the temperature of the cooling water to reach the normal running temperature. Care should also be taken at the same time that the engine does not become too hot, as this will very likely tend to make the adjustment produce a mixture too lean for ordinary running conditions.

72. After the water temperature has become normal, the adjustment is made for the engine running idle, the spark being fully retarded and the lower throttle stop-screw *v*, Fig. 17, adjusted for an idling speed of about 250 revolutions per minute. On turning the screw *m* gradually to the left to make the mixture leaner, a point is reached at which the engine runs unsteadily or stalls. Then the screw should be turned, a notch at a time, to the right to enrich the mixture until a point is reached at which the engine will fire evenly. It is very important that this adjustment should be made while the engine is idling with a fully retarded spark, as this one adjustment, when properly made, automatically insures correct carburetion throughout the entire range of car-operating conditions.

73. Adjustment of Carbureter During Starting Operations.—The dash control, which connects with the lever *l*, Fig. 17, is used for starting and warming up the carbureter. By pulling out the dash button, the metering pin *g* is lowered, thus increasing the size of the fuel orifice. But, as this is done without restricting the air supply, it follows that the fuel mixture can be made sufficiently rich for prompt, efficient starting, and warming up in cold weather without flooding the engine with excessive quantities of raw fuel, as is the case when the engine is started by restricting the air supply by means of a choke valve.

When starting with a cold engine, the dash control should be pulled out entirely, and then, as soon as the engine starts, partly returned. To what point the dash control should be returned during the warming-up process will depend on the weather conditions. During the summer months the button need not be pulled out more than a short distance; but, during extremely cold weather, it may be necessary to leave the control pulled out halfway for part of the warming-up period.

As a general rule, the amount by which the mixture should be enriched by means of the dash control for warming-up purposes should not be more than is absolutely necessary for obtaining satisfactory results. As soon as the engine attains a normal running temperature, the control should be pushed all the way in. If this is not done, a large amount of fuel will be wasted.

74. The starting of the engine under extremely cold weather conditions should be done in the following manner: The spark should be advanced nearly to the running position and the throttle lever on the steering column set, so that the throttle is opened only a little; that is, just a little beyond the idling position. The dash control is pulled out entirely while the engine is being cranked.

When the engine begins to fire, the dash control should remain in its outermost position and the throttle lever left as for starting, permitting the engine to run for 8 to 10 seconds. This will allow the combustion-chamber walls to become some-

what heated, when the control can be pushed part way in and the engine accelerated, as may be required.

The above procedure applies only to cold weather. Under ordinary weather conditions the dash control should at once be returned part way or as soon as the engine begins to fire.

MARVEL CARBURETERS

MODEL H CARBURETER

75. Construction.—Different models of carbureters, to suit different conditions, are manufactured by the Marvel Carbureter Company, Flint, Michigan; all of these embody the same principles of operation and are adjusted in the same manner. In most of the Marvel carbureters some of the exhaust gases are permitted to circulate through a jacket built around the throttle chamber and, in some cases, including also the Venturi tube. In many cars provision is made for supplying the carbureter, which has a single air inlet, with air preheated by being drawn over the exhaust pipe.

76. The Marvel, model H, carbureter, shown in cross-section in Fig. 18, operates on the same general principle as employed in the older model E, but differs from it in some details of construction. Chief among these alterations are the unjacketed Venturi tube *a*, placed in the insert *b*, which is housed by the mixing chamber *c*. Other new features are: The dashpot *d*, which is interconnected with the air valve *e*; the modified air-valve spring *f*, which, in this model, is placed inside of the nut *g*; and, finally, a more effective application of the exhaust gases to the heating of the carbureter.

The dashpot *d* is located on the under side of the insert and contains a loose-fitting piston *h*. The dashpot fills with gasoline automatically, the supply of gasoline coming from the backwash of the mixing chamber *c*, when the carbureter is choked for starting. The plunger of the dashpot, being interconnected with the air valve *e* by the rod *i*, counteracts the

tendency of the air valve to open too quickly, when the motor is accelerated, thus assisting in a quick acceleration or pick-up of the engine.

The spring *f* which exerts the necessary pressure to hold the air valve *e* on its seat, is housed inside of the air screw *g*, and is connected with the air valve by means of the connecting-rod *j*.

77. Operation.—The general operation of the Marvel, model H, carbureter, Fig. 18, is as follows: When the engine is running at low speed, the auxiliary air valve *e* remains closed;

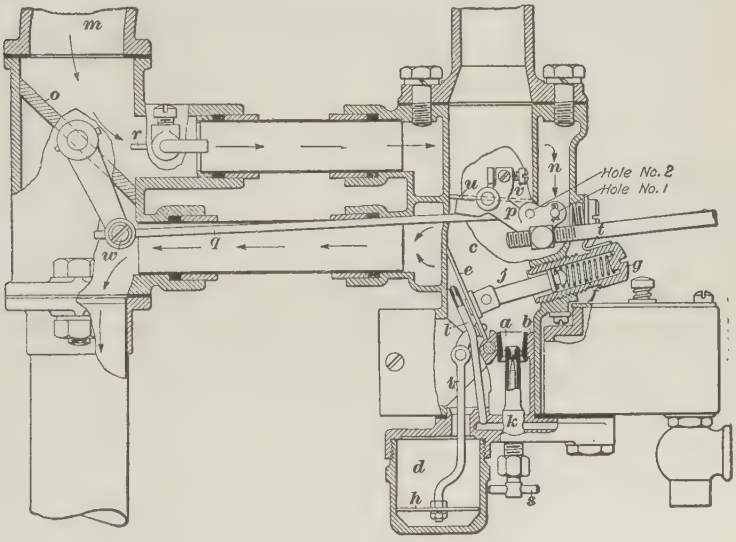


FIG. 18

the air from the air inlet then enters the passage between the spray nozzle *k* and the wall of the Venturi tube *a*, where it mixes with the gasoline vapor from the spray nozzle and from there passes into the cylinders. As the speed of the engine is increased, the increased vacuum in the mixing chamber *c* causes the auxiliary air valve *e* to open, and the high-speed nozzle *l* comes into action.

78. The heat-controlling apparatus of the model H carbureter, Fig. 18, consists of a series of pipes by which the

exhaust gas is carried from the exhaust pipe *n* through the carbureter jacket and back to the exhaust pipe again. The extent to which the exhaust gas is permitted to enter the carbureter jacket *n* is controlled by the valve *o*, which is operated from the throttle lever *p* through the connecting-rod *q*, and also by means of the valve *r*, which is operated by hand.

It will be seen from the illustration that when the valve *r* is open and the valve *o* is in its closed position, all of the exhaust gases will be deflected through the carbureter jacket *n* around the gasoline passage, and back to the exhaust pipe *n*. It is obvious, then, that, by varying the position of either or both valves *o* and *r*, any volume of heat from the exhaust may be obtained, as required.

79. Adjustments.—The proper heat setting of the Marvel, model H, carbureter, Fig. 18, is made by means of the small valve *r* and the two holes Nos. 1 and 2 in the throttle lever *p*. One end of the rod *q* is inserted in hole No. 1; the valve *o* is fully closed and the valve *r* fully open, the throttle valve *s* being in its idling position. This setting, which is known as No. 1, provides for the most heat obtainable, and should be used during the entire year except in extreme cases, as when the engine is losing power due to the excessive heat of hot climates or unduly hot seasons, or when high-test gasoline is being used in the engine.

If this loss of power is experienced when the engine is otherwise known to be in good working condition, the end of the connecting-rod *q* should be removed from hole No. 1 in the throttle lever and placed in hole No. 2. The valve *r* should not be moved from its fully open position during this change. This setting, which is known as No. 2, provides all of the regulation of the heat required, except in the extreme conditions of climate and fuel already mentioned. The valve *r* must never be disturbed, except as a last resort, after setting No. 2, together with the air regulator on the dash set at *cold* after the engine has warmed up, has failed to produce the desired result.

If there is still an indication of too much heat, as evidenced by a continued loss of power, valve *r* may be closed somewhat

until the engine runs properly. This final setting is known as No. 3. Under no circumstances should valve *r* be other than fully open when the connecting-rod *q* is in the No. 1 hole of the throttle lever.

MODEL K CARBURETER

80. Construction.—The Marvel, model K, carbureter, as applied to Buick cars, differs from the model H only in the position and design of the dashpot. The dashpot for the model K is shown in Fig. 19. In this design the air-valve adjusting screw *a* is made in the form of a shell into which the piston *b* fits, thus forming a dashpot. The connecting-rod *c*, acting on two hinged joints, connects the air valve *d* with the dashpot piston *b*. Owing to the vacuum existing within the shell *a*, the plunger *b*, is kept constantly lubricated by fuel being drawn into the shell from the mixing chamber.

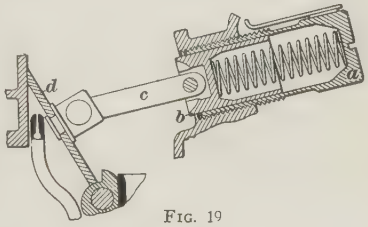


FIG. 19

81. The installation of the Marvel, model K, carbureter on the Nash car is identical with that just described, except that the valve *r*, Fig. 18, is connected with the larger valve *o*. The reason, as advanced by the manufacturers, is that the temperatures tended to run slightly higher in Nash cars than in Buick cars, because of the form of manifold used, and the two valves were interconnected to prevent any chance of overheating under unusual climatic conditions.

82. In the Marvel carbureter used on the Oakland car, a hot spot is provided in the intake manifold, and the charge temperatures run from 70° to 90° higher than in the Buick cars, as the Buick has no direct connection between the intake manifold and the exhaust gases. Because of these high-charge temperatures the valve *r*, Fig. 18, is connected with the valve *o* in the Oakland cars, to prevent overheating.

83. Adjustments.—The adjustment of the Marvel carbureters, which, on the whole, is performed in the same manner

on all models, may be made according to the following instructions, it being understood that, as models H and K have adjustable heat settings, they should have these adjustments set for No. 1, before attempting to adjust the carbureter.

The first step is to turn the gasoline-adjusting screw, which is shown at *s*, Fig. 18, and is the same for the other models, to the right until the needle valve rests gently on its seat. This movement of the valve should be made very carefully, so as not to injure the needle point. It is then turned to the left about seven-eighths of a turn to open the valve slightly.

The second step is to set the air-adjusting screw *g* so that the outer end of the screw is even with the end of the ratchet set-spring *t* above it. The engine should now be started and allowed to run long enough to warm up, the air regulator on the dash being turned toward Hot as the engine warms up, finally being left at Hot.

With the spark lever in its fully retarded position, the gasoline-adjusting screw should be turned to the right slowly, thus closing the needle valve, until the engine idles smoothly. The engine is then speeded up to about twice its normal idling speed, and the air-adjusting screw is turned to the left, a little at a time, until the engine begins to slow down or skip, indicating too much air, at which point it is again turned to the right until the engine runs smoothly. The throttle *u* should then be brought to its closed position, and if the engine idles too fast, the throttle lever setscrew *v* should be unscrewed until the engine idles properly.

84. To test the adjustments described in Art. **83,** the spark lever should be advanced and the throttle opened quickly. The engine should accelerate instantly. If it skips or pops back, the gasoline-adjusting screw *s*, Fig. 18, should be turned slightly to the left to admit more gasoline. The air-adjusting screw *g* should not be touched unless it appears absolutely necessary The best carbureter adjustment is obtained when the gasoline-adjusting screw is turned so as to open the needle valve about three-fourths of a turn, and the air adjustment carried as lightly as possible for quick acceleration with a fully

advanced spark. The normal position of the air screw is, as already stated, with its outer end about even with the end of the ratchet set-spring above it.

85. In models H and K, after the carbureter has been adjusted as just described, and the throttle is set for proper idling, the connecting-rod *q*, Fig. 18, from the valve *o* in the exhaust pipe to the throttle lever *p*, should be readjusted so that the valve *o* will be closed when the engine is idling and the heat adjustment is in setting No. 1. This adjustment may be made by loosening the locknut *w* and moving the rod *q* in or out, as required.

Changes in air-valve springs should never be made, unless the operator is sure that he has the correct size of spring for the carbureter on which he is working. It is important to observe this rule, as these springs vary according to their installation, and are tested for size and tension to meet the requirements of the particular size of engine for which they are intended.

FORMS OF CARBURETERS
(PART 2)

CONSTRUCTION AND ADJUSTMENT
(Continued)

JOHNSON CARBURETERS

CARBURETER, MODEL A, WITH DASHPOT

1. Construction.—Several models of Johnson carbureters are made by The Johnson Company, Detroit, Michigan, all of them embracing the same principle of operation. Those intended for eight-cylinder engines are fitted with a so-called accelerator pump or dashpot, which is interconnected with the throttle valve and comes into operation only when the throttle is quickly opened, temporarily enriching the mixture to give a rapid acceleration to the car.

In Fig. 1 is shown a carbureter known as "Model A with dashpot." The side view (*a*) shows a large portion broken away to disclose the interior construction. View (*b*) is a plan, and view (*c*) a vertical section of the accelerator pump. Gasoline enters the carbureter at *a*, view (*a*), being strained by a fine wire screen *b*. The gasoline enters the float chamber through the needle valve *c* and is maintained at a constant level by the cork float *d*, concentric with which is the spray nozzle *e* controlled by the hand-operated adjusting needle valve *f*. A strangling, or choke, tube *g* is directly above the spray nozzle and is so mounted in the carbureter body that it

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can be partly rotated therein by means of the choke lever h, view (b). In the horizontal flange of the tube g there are a number of ports, which lead from the air chamber i, view (a),

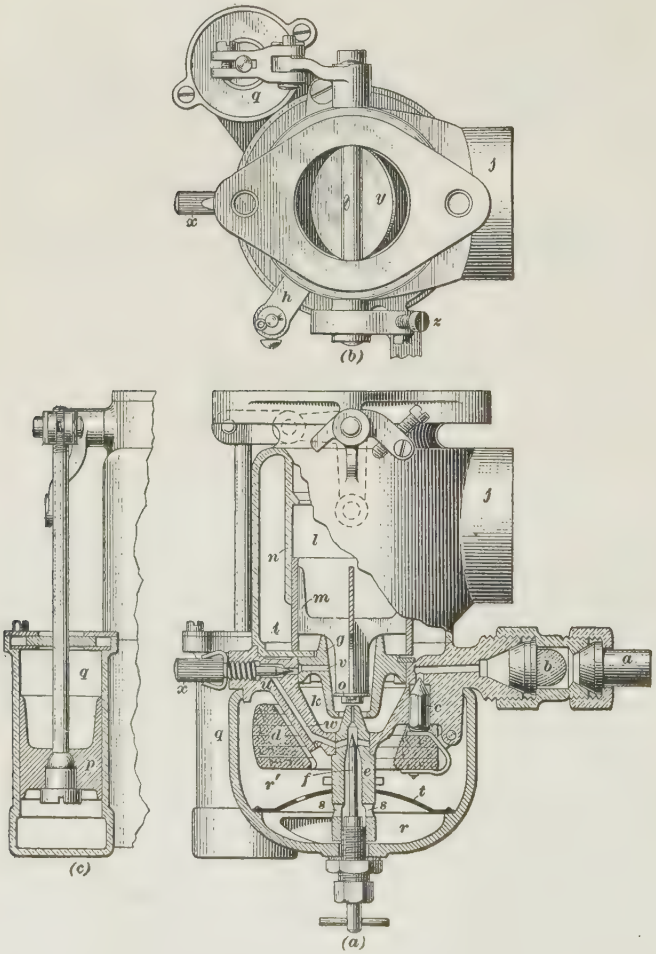


FIG. 1

to the annular chamber k. These ports may be covered or uncovered by moving the choke lever in the required direction. When the ports are partly or entirely uncovered, air can pass

from the air inlet *j* into the air chamber *i* and from there to the chamber *k*. From here the air passes through the annular opening in the bottom of the choke tube *g*, past the spray-nozzle outlet and up into the mixing chamber *l*.

2. In line with the axis of the choke tube *g*, Fig. 1 (*a*), is the circular air valve, or sleeve, *m*, free to slide vertically in the cylindrical guide *n*. This air valve carries a circular lifter plate *o* at its bottom, directly above the top of the spray nozzle *e*. The strangling tube, while capable of partial rotation by means of the choke lever *h*, view (*b*), is confined vertically. The accelerator pump consists of a loosely fitting piston *p*, view (*c*), working in a cylinder *q* open to the atmosphere at the top and connected at the bottom by a passage to the lower float chamber *r*, view (*a*), into which the spray nozzle opens by means of the holes *s*. The upper float chamber *r'* communicates with the lower one *r* through a small passage in the diaphragm *t*. A hole *u*, drilled through the top of the float chamber communicates with a port *v* that leads to the interior of the choke tube *g*. Another port *w* connects with a cross hole drilled through the nozzle *e*. The size of the opening of the port *v* is controlled by the low-speed adjusting screw *x*. The throttle valve *y*, view (*b*), is of the butterfly type, and is supplied with the usual stop-screw *z* by which its closed position can be regulated.

3. Operation.—The operation of the Johnson carbureter, Fig. 1, is as follows: To start the engine, a rich mixture is necessary, which is obtained by moving the choke lever *h*, view (*b*), to open partly the ports leading through the flange of the choke tube *g*, view (*a*), down into the chamber *k*. The air flows up past the spray nozzle *e*, picking up gasoline as it passes the tip of the nozzle, and blowing the mixture directly against the lifter plate *o*. The result is that the combination of fuel and air is sprayed uniformly over the inner surface of the tube *g* and thus thoroughly mixed before it is allowed to proceed on its way toward the cylinders.

4. As soon as the engine begins to fire, the choke lever *h*, Fig. 1 (*b*), is moved to open the air ports wider. On opening

the throttle, the gas-laden air gains enough velocity to raise the lifter plate *o*, view (*a*), and thus lift the air sleeve *m* from its seat, allowing pure air to enter through the annular opening and mix in suitable proportion with the overrich primary air. The more the throttle is opened, the higher the velocity of the air-current; therefore, the higher the sleeve *m* lifts, and the greater the suction acting on the spray nozzle *e*. It follows that at all speeds a uniform mixture of gasoline and air will be delivered to the engine. A sudden opening of the throttle valve will depress the piston *p*, view (*c*), quickly enough to create a slight pressure in the lower float chamber *r*, view (*a*), because the gasoline is forced into it faster than it can pass out into the upper float chamber; hence, some extra gasoline is forced out of the spray nozzle *e* into the choke tube *g*, temporarily enriching the mixture and thus giving quick acceleration.

In order that the best results may be obtained from an engine in cold weather, it is desirable that the radiator shall be sufficiently covered, so that the water will remain at approximately summer temperature; otherwise, it is necessary to drive with the choker pulled out, which not only decreases the gasoline economy but also draws more or less fluid gasoline into the engine, thereby impairing the engine lubrication.

5. Adjustments.—Before the engine is started for the purpose of adjusting the carbureter, care should be taken to see that the throttle opens and closes properly. The high-speed needle *f*, Fig. 1 (*a*), and the idling screw *x* should be screwed in as far as possible. Then, the needle *f* is opened out about two turns and the screw *x* one half turn. Under these conditions the engine can readily be started. But it is desirable that the engine shall not be allowed to run too long with the choke lever *h*, view (*b*), in a closed position.

After the engine has reached the normal driving temperature, the spark should be retarded and the throttle opened far enough to enable the engine to run at a speed of about 1,000 revolutions per minute. Then the needle valve *f* is adjusted to a position that allows the engine to run at its highest speed with the existing throttle position.

6. After the high-speed adjustment is obtained in the manner described, the throttle valve should be closed and the screw *x*, Fig. 1 (*a*), adjusted by turning it to the right, so as to give a lean mixture, as required for an idling speed of about 240 revolutions per minute. While the engine is idling, the entire gasoline supply passes through the port *v*. This adjustment is for idling only and does not affect the throttling; therefore, if the engine cannot be made to idle properly by adjusting the screw *x*, when the spark is retarded, it proves that the engine requires attention at some other place. For instance, the spark gaps and the valve seats should be examined; also, the intake manifold and header should be tested for air leaks.

CARBURETER, MODEL B

7. Construction and Operation.—The Johnson carbureter, Model B, differs from Model A mainly in the addition of an auxiliary air valve. The Model B carbureter is shown in Fig. 2, in which view (*a*) is a side view mostly in section, and view (*b*) a plan. The gasoline passes through the strainer body *a*, past the needle valve *b*, and into the float chamber *c*, where a constant level is maintained in the usual manner by means of the float *d*. The gasoline passes from the spray nozzle *e* into the choke tube *f*, which is of the extended type, the lower restricted end being quite small in diameter. This contraction, together with its position relative to the nozzle, reduces to a minimum the heat required at this point. The fuel jet is regulated by means of the needle valve *g*, to which is attached an indicator arm *h*, which may be adjusted between two extreme positions, marked "Rich" and "Lean" on the outside of the bowl.

8. The mixing chamber *i*, Fig. 2 (*a*), is so shaped that all condensed fuel is drained into a circular groove *j*, provided with a number of small holes through which the gasoline flows into the choke tube and down into the primary air passage *k* that surrounds the nozzle *e*. The arrangement of these parts is such that, when the motor is stopped, all condensation in

the chamber *i* drains into the cup *j* and seals the passage at the lower end of the choke tube. The accumulated gasoline

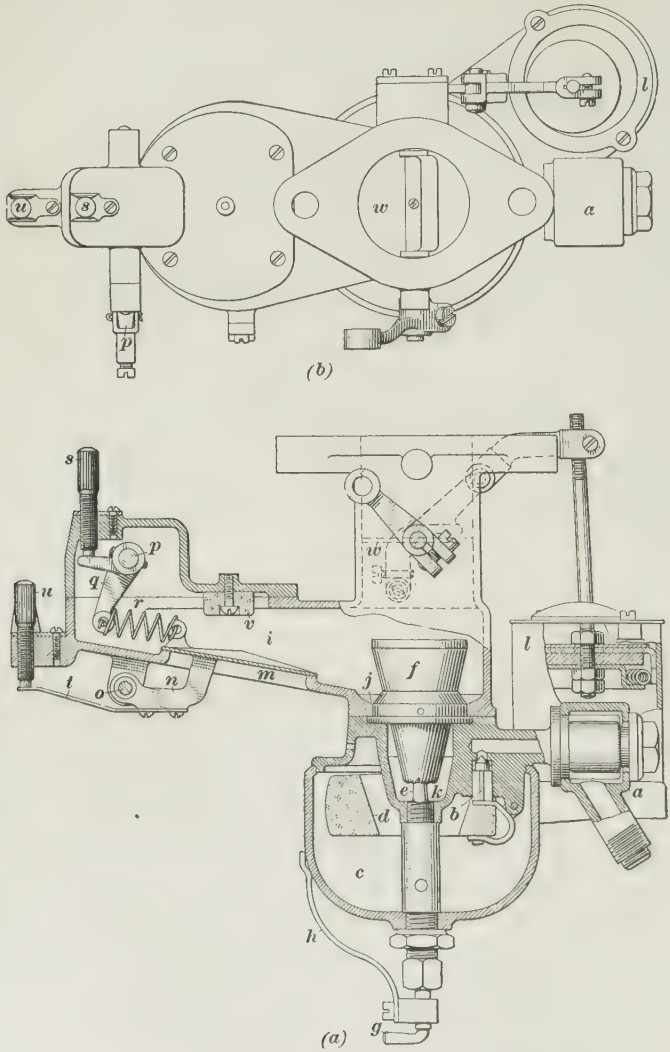


FIG. 2

is again atomized when the motor is started, thus tending, momentarily, to enrich the mixture when the engine starts.

The accelerating pump *l* serves to produce a richer mixture for acceleration, in the manner explained in Art. **4.**

9. The auxiliary air valve consists of a thin metal plate *m*, Fig. 2 (*a*), attached to the arm *n* pivoted on the pin *o*. The valve may be raised or lowered by means of the auxiliary throttle shaft *p*, which may be operated from the dashboard in the usual manner. The shaft *p* is connected to the valve *m* by the arm *q* and the spring *r*, the position of this arm being adjusted by means of the screw *s*. To the arm *n* is screwed a flat, stiff spring *t* that touches the lower end of the adjusting screw *u*. The vacuum produced in the mixing chamber *i* by the engine tends at all times to keep the valve *m* floating in a position some distance above its seat, even when the engine is running at its slowest speed. Therefore, when the valve is pushed to its seat by means of the throttle shaft *p*, a richer mixture is produced, which will facilitate starting in the coldest weather. In its highest position, the valve makes contact with the cork stop *v*. The idling mixture is obtained by the action of the comparatively stiff spring *t*, which ceases to operate as soon as the valve *m* is raised as a result of the suction produced at any speed above the idling one.

10. Adjustments of Models B and BX.—A large letter X, cast on top of the valve cover, distinguishes Model BX from Model B. As the adjustments of these models are identical, except at one point, subsequently noted, they will be considered under one head. Before any adjustment of the carbureter, Fig. 2, is attempted, the entire ignition system, the engine valves, and the gasoline feed to the carbureter should be inspected, so as to make sure that the carbureter itself really needs adjusting. Then the engine should be run long enough to enable it to reach a normal driving temperature. During the adjustment, the choke control on the dashboard should be in the off-position, and the screw in the choke lever on the carbureter should be loosened to permit the lever to move freely while the adjustment is being made, after which a slack of about $\frac{1}{8}$ inch should be left, before the lever again is fastened in place.

11. The adjustments of the carbureter, for the purpose of regulating the relative proportions of gasoline and air in the mixture, should be made in the following manner and order: Under normal conditions the standard adjustment of the spray needle *g*, Fig. 2 (*a*), is to open it about $1\frac{1}{8}$ turns from its closed position. In the Model BX the needle *g* should be turned back $1\frac{1}{2}$ turns from its closed position. The indicator *h* should occupy a position half way between the words "Rich" and "Lean," cast on the bowl *c*. By moving the indicator either to the left or to the right, the adjustment may be slightly varied to suit the existing conditions. For the purpose of checking the adjustment, the throttle *w* should be opened to a point at which the engine runs at a speed high enough to lift the valve *m* into contact with the stop *v*. Then, if the indicator *h* is moved toward "Lean," the motor should slow down. Next, the indicator should be moved back gradually until the engine reaches its maximum speed with that throttle setting. Care should be taken to make sure that the vibrations of the engine have not altered the position of the throttle while the adjustments were being made. This test should not be undertaken before the engine has been thoroughly run in, as running an engine idle at high speed tends to abuse it.

12. The auxiliary valve *m*, Fig. 2 (*a*), may be adjusted by means of the screw *s*. It is assumed that before this adjustment is begun, the needle *g* has been adjusted in the manner described in Art. **11.** On turning the screw *s* to the right, the mixture will be enriched, and it will be made leaner by turning the screw to the left. Preliminary to this adjustment, the throttle should be opened, by means of the hand-controlled lever, until the engine runs at a speed of about 600 revolutions per minute, which corresponds to a car speed of from 10 to 12 miles per hour on the road. Then the screw *s* should be turned to the right until the engine begins to slow down from too rich a mixture. The screw is next turned to the left, a little at a time, with a pause of a few seconds after each movement of the screw to allow the change in adjustment to take effect. As

the mixture becomes leaner, the engine speed will first increase and then decrease. The turning of the screw should cease as soon as the speed begins to decrease.

13. The adjustment for idling must not begin before the previously described adjustments have been completed. First, the engine is stopped; then the screw *u*, Fig. 2 (*a*), is turned to the left until it ceases to make contact with the spring *t*. The screw is then turned to the right until it just touches the spring. When the engine is started, this adjustment will cause a slightly overrich mixture, and to correct it the screw must be turned to the right until the proper mixture is obtained. The only adjustment required for the accelerating pump is to allow $\frac{1}{16}$ inch clearance between the plunger and the bottom of the cylinder, when the throttle is wide open.

CARBURETER, MODEL R

14. Construction and Operation.—The Johnson carbureter, Model R, corresponds in all respects to Model B, Fig. 2, except in the construction of the auxiliary air valve. The following description will therefore be limited to a consideration of this valve in conjunction with the adjoining and interacting parts. Fig. 3 is a side view, partly in section, of one end of a Model R carbureter, which contains the auxiliary air valve, the remainder being omitted, as it corresponds with Model B, Fig. 2.

It may be said that the auxiliary valve shown in Fig. 2 is inverted in Fig. 3, it being attached to the top of the mixing chamber, instead of the bottom. In the side view, Fig. 3, *a* is the mixing chamber, and *b* the auxiliary air valve, hinged at its right-hand end to the casting *c*. The spring *d* tends to force the valve upwards against its seat, the screw *e* regulating the effective opening between the valve and its seat while the valve occupies its uppermost position. To prevent the fluttering action to which the air valve ordinarily is subjected, it is connected by means of the rod *f* to the cork float *g*, submerged in the fuel contained in the special chamber *h*, which is in direct communication with the main float chamber *i*. The

float *g* being submerged, it follows that in all positions of the valve *b* the upward pressure of the float is constant. The driving-range adjustment of the air valve is made by means of the screw *j*.

15. Adjustments.—The adjustment of the spray needle, which corresponds in position and construction with that of *g*, Fig. 2, is approximately correct when the needle is opened $1\frac{1}{8}$ turns from the fully closed position. This rule applies to the $1\frac{1}{4}$-inch size carbureter. The larger opening required for larger sizes or for special cases may be determined by trial for power or speed with wide open throttle. With the air valve *b* in a wide open position, the other adjustments are out of action. To make the mixture lean the spray needle is turned so as to move upwards.

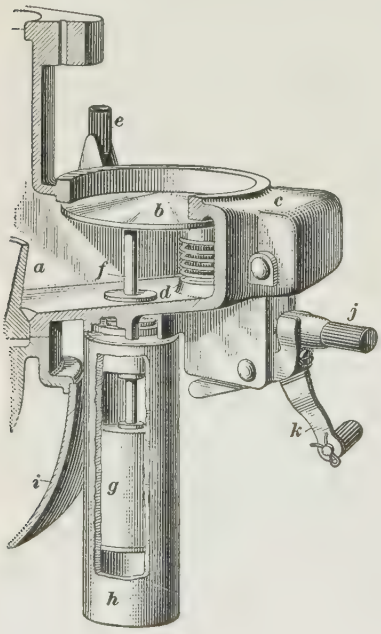


FIG. 3

16. The adjusting screw *j*, Fig. 3, which regulates the mixture through ordinary driving speeds, should be set after the engine has warmed up to its normal temperature, and after the spray-needle adjustment is made. First, the hand throttle should be opened to give the engine a speed of approximately 400 revolutions per minute, or a car speed of 10 miles per hour. When the screw *j* is turned clockwise it compresses the spring *d* and enriches the mixture; consequently, by turning the screw counter-clockwise the mixture is made leaner. Before this adjustment is made, it is necessary to turn the screw *e* counter-clockwise until it is out of contact with the valve *b* in its closed position. Next, the screw *j* should be

turned counter-clockwise until the engine by reason of a lean mixture is losing speed. Then, the screw is turned clockwise, a few notches at a time, until the highest speed is obtained with the throttle setting at which the adjustment is being made. After each adjustment of the screw, sufficient time should be allowed the engine to respond to the change in mixture.

The final setting may be checked as follows: If by a slight depression of the valve *b*, or by a slight pull on the lever *k*, the speed decreases, the setting has been secured for a correct mixture.

17. The idling adjustment is made by means of the screw *e*, Fig. 3, in the following manner: The throttle valve should be fully closed and the spark retarded. If the other adjustments are correctly made, the idling mixture may be found to be too rich, in which case it is made leaner by turning the screw *e* clockwise, and richer by turning it counter-clockwise. It is supposed that the stop-screw in the throttle lever has been set in the usual manner, as explained in Art. **5**. The adjustment made by means of the screw *e* is independent of the two other adjustments, because this screw is out of contact with the valve as soon as it leaves its closed position.

CADILLAC CARBURETERS

CARBURETER OF EIGHT-CYLINDER CADILLAC

18. Construction.—The carbureter manufactured by the Cadillac Motor Car Company, Detroit, Michigan, for use on its eight-cylinder **V**-type engines, is shown in perspective in Fig. 4. The opposite side of the carbureter is shown in Fig. 5, with part of the outer wall cut away so as to disclose the interior construction. Similar parts have been lettered alike in both illustrations, and both should be referred to in reading the description. The carbureter is of the single-jet type, and has an auxiliary air valve by which the correct mixture is automatically maintained at all engine speeds and throttle open-

ings. In addition, provision is made for further regulation of the mixture by an accelerator pump and an automatic *leaning device,* both of which are positively interconnected with the throttle.

Gasoline enters the carbureter at *a,* passing through a wire-gauze strainer and the passage *b* to the float chamber *c,* which is directly under the mixing chamber *d.* The height to which the fuel rises in the float chamber *c* is regulated by the cork float *e* and the needle valve *f.* The spray nozzle *g,* which is located in the center of the chamber *c* and extends into the

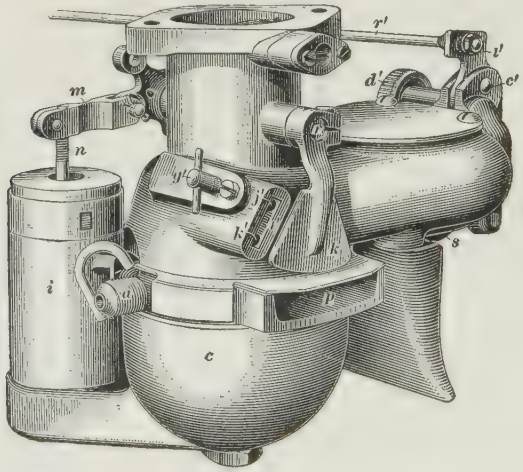


FIG. 4

small end of the Venturi tube *h,* is not adjustable. The plunger *i* of the accelerator pump is connected to the throttle lever by the arm *m* and the connecting-rod *n*; consequently, if the throttle *o* is opened quickly, the plunger *i,* in descending, forces gasoline through the spray nozzle *g* into the mixing chamber *d,* where it mixes with the air passing from the main air intake *p* and the auxiliary air intake *q* to the engine cylinders, thus giving a rich mixture for quick acceleration. The accelerating device may be used for priming the carbureter by opening and closing the throttle rapidly a few times before the engine is started.

19. The leaning device consists of a shutter *k*, Fig. 4, fastened to the right-hand end of the throttle shaft *r* and so located that it covers a slot *i'* in the carbureter at small throttle openings, and uncovers it when the throttle is opened wide or nearly so. Two holes *j'* and *k'* are drilled from this slot through the carbureter body, the hole *j'* leading to the mixing chamber *d*, as shown at *j'*, Fig. 5, and the other leading to the air space above the gasoline in the float chamber *c*. When the slot *i'* is covered by the shutter *k*, this slot is changed into a covered channel that connects the holes *j'* and *k'*. Hence, direct communication is established between the mixing cham-

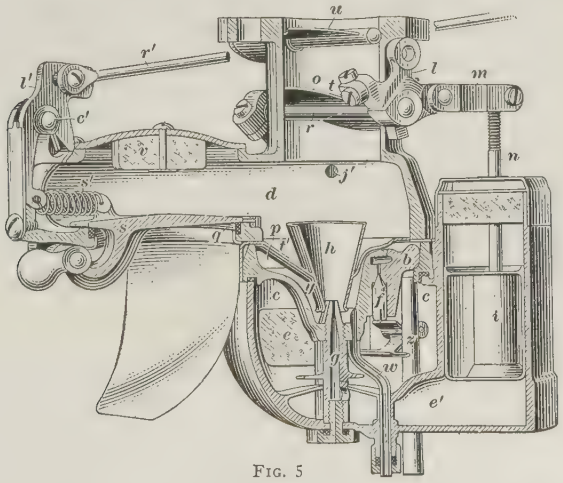


FIG. 5

ber *d* and the gasoline chamber *c*. Consequently, the air is partly drawn out of the gasoline chamber *c*, by the partial vacuum in the mixing chamber *d*, with the result that less gasoline is fed through the spray nozzle *g*. When the throttle is opened wide, the shutter *k* uncovers the slot *i'*, thus opening the gasoline chamber *c* to the atmosphere and causing a normal flow of gasoline from the spray nozzle *g*.

The auxiliary air opening *q* is controlled by a leather-seated swing valve *s*, governed by an adjustable spring *s'* of light tension. The tension of the spring *s'* is varied by the lever *l'* pivoted at *c'*, and connected to a rod *r'*.

20. The throttle valve *o* is of the usual butterfly type, with a stop-screw *t* for adjusting its closed position. A so-called auxiliary throttle *u*, also of the butterfly type and having one wing shorter than the other, is placed just above the main throttle *o*. At low engine speeds the throttle *u* remains closed, there being sufficient room between the edge of the short wing and the wall of the gasoline passage for the mixture to pass. As the main throttle valve *o* opens for an increase of speed, the resulting air-current will likewise open the auxiliary throttle *u* against the pressure of a light spring, and give an unrestricted passage to the mixture entering the engine cylinders. The function of the auxiliary throttle *u* is to prevent the fluttering of the auxiliary air valve *s*. The quiet action of the auxiliary air valve is further assisted by the cork bumper *v* so located that the valve *s* when wide open strikes against it, instead of against the upper wall of the mixing chamber *d*. The carbureter is provided with two drain tubes, the one shown at *w* leading from the bottom of the air passage *y*, and the other, shown at *z*, extending into the gasoline chamber *c*, thus preventing the gasoline from rising above the desired level.

21. Operation.—The operation of the Cadillac carbureter, Fig. 5, is as follows: To start the engine, the end of the rod *r'* in the front compartment is pushed forward, causing the lever *l'* to swing on its pivot *c'*, thereby increasing the compression of the spring *s'*. The auxiliary air valve *s* thus offers greater resistance to opening, and, consequently, when the engine is cranked, air enters the mixing chamber *d* through the main air intake *p* only, and a strong suction is produced at the spray nozzle *g*. This gives a rich mixture for starting. As soon as the engine fires, the rod *r'* is pulled back, relieving the tension of the spring *s'*. As the engine speeds up, air enters the mixing chamber *d* through the auxiliary air intake *q*, as well as from the main air intake *p*. The air from the main air intake *p* is deflected by the baffle plate *t'* to the bottom of the Venturi tube *h*, whence it passes through the tube, exerting a suction on the top of the spray nozzle *g*. Gasoline issues

from the spray nozzle *g* and mixes with the air in the mixing chamber *d*, the proportion of gasoline to air thus being automatically regulated to conform to the different speeds of the engine. The piston *i* of the accelerator pump creates a pressure on the gasoline in the lower part of the chamber *e'* when the throttle *o* is open suddenly, forcing some of the gasoline out of the spray nozzle *g*, temporarily enriching the mixture and giving a quick acceleration of the engine. At very high speeds, the leaning device permits air to enter the gasoline chamber *c*, thereby increasing the proportion of air to gasoline.

22. Adjustments.—To adjust the carbureter, Fig. 5, the throttle is opened by moving the throttle lever on the steering-wheel sector about 2 inches, and the spark lever is placed in the "Driving Range," as marked on the sector. The engine is then run until the water-jacket is hot. With the throttle slightly open and the spark fully retarded, the adjusting screw *d'*, Fig. 4, is turned counter-clockwise until the engine backfires, and then turned clockwise, one notch at a time, until the engine runs at its highest speed. Screwing in the adjusting screw *d'* increases the tension of the closing spring *s'*, and enriches the mixture, while unscrewing it weakens the mixture.

The throttle is adjusted for idling speed by moving the throttle lever to its closed position, and screwing the stop-screw *t* in or out until a point is reached at which the engine runs at a speed of about 300 revolutions per minute. The spark is fully retarded during this adjustment. The adjusting screw *d'* is then turned until the engine runs at its highest speed with the spark fully retarded and the throttle lever in its fully closed position.

23. The adjustment of the leaning device is made at the screw *g'*, Fig. 4. With the throttle open until the shutter *k* just covers the slot *i'* in the carbureter body, the screw *g'* is turned counter-clockwise, thus weakening the mixture to a point where the engine produces the highest speed, and where any further turning of the screw *g'* would cause the engine to slow down. During very cold weather, it is advisable to turn the screw *g'* in, thus giving a slightly richer mixture.

The accelerator pump is also adjustable, but the adjustment is properly made at the factory, and should require no further adjustment. In case the adjustment is changed, unintentionally or otherwise, the rod *n* should be turned until its upper end is flush with the upper surface of the arm *m*.

CADILLAC CARBURETERS, LATER TYPE

24. Construction and Operation.—In the later type Cadillac carbureters, certain modifications are introduced to make the older model, Fig. 4, more nearly automatic in its action and thus more independent of the control of the operator.

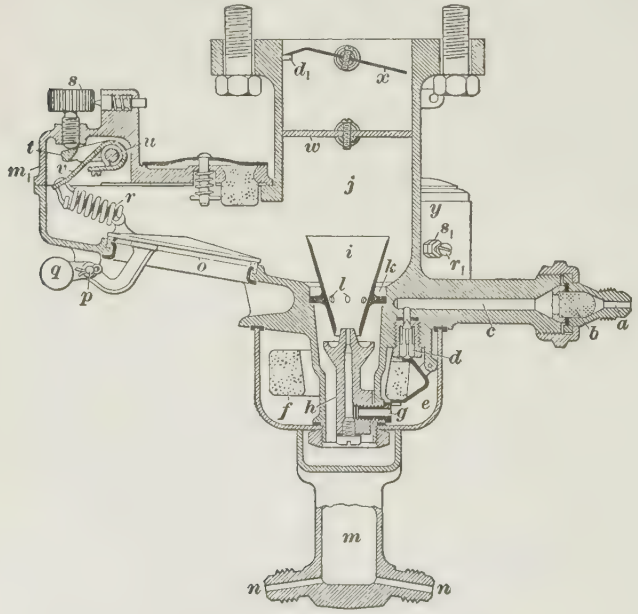


Fig. 6

For this purpose a number of thermostats have been added that serve to regulate the action of the auxiliary air-valve spring and of the accelerator pump. In Fig. 6 is shown a longitudinal section of the carbureter, from which the accelerator pump and some of the automatic devices are omitted.

The gasoline entering at *a* passes through the strainer *b* and the channel *c*, past the needle valve *d*, and into the float chamber *e*, where the float *f* maintains it at a fixed level. The fuel flows through the port *g* into the spray nozzle *h*, located in the center of the chamber and extending into the lower end of the Venturi tube *i*. Gasoline vapor that may condense on the walls of the mixing chamber *j* flows into the groove *k* and through the holes *l* into the cup-shaped rim at the upper end of the nozzle *h*. Here the accumulated gasoline will again be atomized by the strong air-current that passes this point and sent through the Venturi tube into the mixing chamber *j*. Attached to the float chamber is a catch basin *m* that collects any gasoline that may overflow from the nozzle and then sends it through the outlets *n* into drainage tubes attached to them.

25. The auxiliary air valve *o*, Fig. 6, is pivoted on the pin *p* and counterbalanced by the ball *q* as in the earlier model. The spring *r*, which tends to force the valve *o* to its seat, is adjusted by means of the screw *s* through the intervention of the lever *t*, pivoted on the pin *u*, and the thermostatic spring *v*. When the temperature increases, the free end of the spring *v* will move to the left and decrease the pressure of the spring *r* on the valve *o*, thus allowing the latter to admit more air. With a decrease in temperature, the spring *v* will bend to the right and prevent the valve *o* from rising so high. At *w* is the throttle valve and at *x* the automatic throttle that prevents any fluttering of the auxiliary valve *o*.

26. A rear view of the carbureter, Fig. 6, is shown in Fig. 7 (*a*), in which corresponding parts are indicated by the same letters. An interior view of the accelerator pump *y* is not shown, as it corresponds in its main features with similar pumps. Its distinguishing feature in this model is that its piston does not come in direct contact with the gasoline, but only with the air contained in the upper part of the float chamber. By depressing the piston the air is compressed and an increased amount of gasoline is sent to the nozzle *h*, Fig. 6. In Fig. 7 (*a*) is shown the connection between the plunger rod *z* of the accelerator pump and the upper arm of the double

lever a_1, the lower arm being connected to the rod that leads to the dash control. In the lug b_1 there is a stop-screw that makes contact with the head of the stationary screw c_1, thus fixing the position of the throttle valve when closed. When the lever a_1 is quickly turned counter-clockwise the pump rod z is forced downwards and increases the gasoline supply, as explained. But when the throttle lever is moved down slowly the pump does not affect the fuel supply to the spray nozzle.

27. The automatic throttle valve x, Fig. 6, is forced against the stop d_1 by a helical spring contained in the bear-

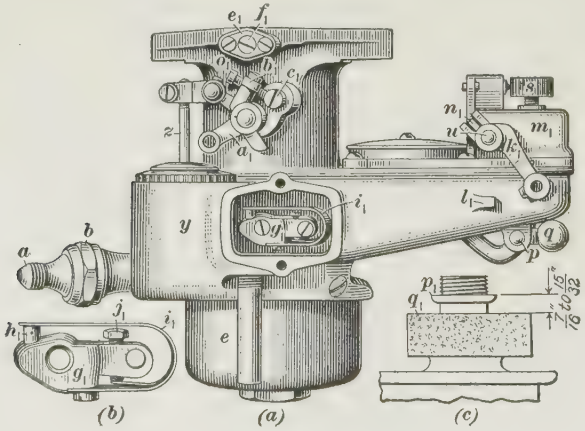


FIG. 7

ing e_1, Fig. 7 (a). The tension of this spring may be adjusted by loosening the screws in the bearing cap and turning the screw f_1 in the required direction. In the right-hand half of the valve x, Fig. 6, are a number of perforations that serve to unbalance the valve; that is, the air-current coming from below will exert a greater pressure on the left-hand half of the valve and therefore turn the valve in a clockwise direction until the helical spring prevents further motion. The valve will then have opened sufficiently far to allow an unrestricted passage of the fuel mixture to the cylinders. At low engine speeds the valve x remains closed, but the combined area of the valve perforations is sufficient to allow the fuel mixture to pass.

28. The recess that contains the block g_1, Fig. 7 (*a*), on which is mounted a thermostat, is shown uncovered. The block is shown separately and enlarged in view (*b*). Through the lug h_1 is drilled a vertical air vent that connects with the air in the float chamber. It follows that, if air is allowed to escape through the vent in the lug h_1 when the pump rod z is descending, the resulting pressure will be lower and less fuel will be forced through the spray nozzle. The air-current that may pass through the vent in the lug h_1 is controlled by the thermostat i_1, attached to the lower side of the block g_1. Depending on whether the thermostat is subjected to an increase or a decrease of temperature, the free end of the thermostat will move away from or toward the lug h_1, and in the latter case will close the vent. A short branch of the thermostat is in contact with the lower end of the adjusting screw j_1. Under normal temperature the vent is closed by the thermostat; but with an increase in temperature the free end will move away from the lug h_1 and uncover the vent.

29. Later types of the carbureter shown in Fig. 6 are fitted with two thermostats, attached side by side to the block g_1, Fig. 7 (*b*). The object of the additional, or high-temperature, thermostat is to control another and larger vent during hot weather, a desirable feature when high-test gasoline is used. These double thermostats are of the two following types: (*a*) The high-temperature thermostat, which is the inner one of the two; (*b*) the low-temperature thermostat, which is the outer one.

30. Adjustments.—The adjustment of the auxiliary valve o, Fig. 6, may be tested in the following manner: When the lever k_1, Fig. 7 (*a*), attached to the pin u, Figs. 6 and 7 (*a*), is pushed forwards against the stop l_1, the tip of the valve o, Fig. 6, should, at a room temperature of from 65° to 85° F., open inwards a distance of $\frac{1}{16}$ to $\frac{1}{8}$ inch, when pushed lightly upwards with the finger. This pressure should not be so great as to bend the thermostatic member v. If this valve motion is greater or smaller than required, the cover m_1, Figs. 6 and 7, (*a*), should be removed and the lever t, Fig. 6, to which the

member v is attached, loosened and readjusted. Care must be used in removing the cover m_1 to avoid stretching the spring r. The latter should be unhooked as soon as the cover is lifted high enough to permit it. No attempt should be made to repair a stretched or bent spring; it should be replaced by a new one. When the enrichment button on the dashboard is pushed all of the way in, the tongue n_1, Fig. 7 (a), should stand in the center of the stationary slot seen behind it. If not, the necessary adjustment must be made.

31. Before the pressure of the spring r, Fig. 6, can be regulated by means of the screw s, the adjustment of the tongue n_1, Fig. 7 (a), must have been made. Likewise, the throttle w, Fig. 6, must have been tested and adjusted in the following manner: After the engine is started and allowed to run until the manifold is of the normal driving temperature, the spark lever is placed in the retard position and the throttle lever in the closed position. The engine speed should then be about 300 revolutions per minute. If the engine runs faster, the screw o_1 in the throttle lever a_1, Fig. 7 (a), should be unscrewed until the engine speed is as required. In case the adjustment of the screw a_1 fails to give the desired results, the setscrew in the small collar at the end of the control rod running to the lever a_1 should be loosened. If the speed is less than 300 revolutions per minute, the lever a_1 is turned counter-clockwise until the speed is increased to about 300 revolutions per minute.

32. To ascertain whether the spring r, Fig. 6, requires adjustment, the two following tests should be made: (1) The ball q is pressed down gently to see whether the raised valve o causes an increase or decrease in engine speed. The ball is then released and the engine is allowed to run for a few seconds to regain its normal speed. (2) The ball q is now lifted gently and the effects are noted.

If the mixture is correct, the results of both tests are identical; that is, there is a slight decrease in speed. But, if the first test causes an increased engine speed and the second one a decreased speed, a *rich* mixture is indicated. On the other

hand, if the first test causes a decrease in engine speed, and the second one an increase, a *lean* mixture is indicated. If these tests indicate an incorrect mixture, the screw s is turned clockwise to enrich the mixture and counter-clockwise to make it leaner. The screw should be turned only a few notches at a time. With the throttle lever a_1 in the closed position, the engine should now run at a speed of about 300 revolutions per minute. If it does not, the screw o_1 should be adjusted until this speed is obtained. After the screw is locked into place, the collar at the end of the control lever should be adjusted in such a position that the throttle w will start to open as soon as the throttle lever is moved. The correctness of the mixture is now tested as before and the screw is readjusted, if necessary. If the test indicates a correct mixture with the throttle lever in the closed position and the engine running at 300 revolutions per minute, the adjustment of the spring r is correct.

33. The thermostat i_1, Fig. 7 (a) and (b), may be adjusted in the following manner: The block g_1 is detached from the carbureter body, care being taken not to injure the gasket inserted behind it. To ascertain whether the thermostat will close the vent at a temperature of 75° F. and just open it at 77° F., two dishes filled with water are provided, the water in one having a temperature of 75° F. and that in the other a temperature of 77° F. When the thermostat is immersed in the water in the first dish and then removed, the vent hole should be closed. If not, the screw j_1 is readjusted. On immersing the thermostat in the water in the second dish, the vent should just be open; if not, the screw j_1 is adjusted.

34. Cadillac carbureters of the type shown in Fig. 6 are also furnished with two vent-control thermostats, the supplementary one being intended to operate at higher temperatures during hot weather. If this high-temperature thermostat is the inner one of the two, it should be adjusted to temperatures between 140° and 150° F. If the high-temperature thermostat is arranged outside the regular one, it should be adjusted to temperatures varying between 115° and 120° F. In either

case the test is performed as explained in Art. **33.** In case the gasket, situated behind the block g_1, is damaged during any of these tests, it must be replaced by a new one.

35. If the adjustment of the float f, Fig. 6, has been tampered with, it is necessary to detach the carbureter from the engine and to remove the bowl e. Then, on turning the carbureter upside down, as shown in the detail view, Fig. 7 (c), where the bowl is shown broken away, there should be a distance between the flange p_1 and the bottom face q_1 of the float of from $\frac{7}{16}$ to $\frac{15}{32}$ inch. It is to be noted that this measurement is made after the cork gasket on the flange p_1 has been removed.

36. Additional means for reducing the pressure in the bowl e, Fig. 6, produced by the downward motion of the piston in the accelerator, is formed in the screw r_1. This screw enters a by-pass between the vent controlled by the thermostat i_1 and the bowl e. When the screw is in its closed position, seven turns in a counter-clockwise direction will fully open the by-pass. The extent to which the screw r_1 must be opened out will depend on the quality of the gasoline and on the atmospheric temperature. Ordinarily, if an adjustment is required, it is sufficient to move the screw clockwise two or three turns. The screw should then be locked with the locknut s_1.

RAYFIELD CARBURETERS

CARBURETER, MODEL GL

37. Construction.—The Rayfield carbureters, Models G, L, GL, LL, M, and MR, manufactured by the Beneke & Kropf Manufacturing Company, Chicago, Illinois, all operate on the same general principle, and are of the type having two non-adjustable auxiliary air valves, differing in this respect from the earlier Models A, AA, B, BB, C, CC, D, DA, E, EE, and H, which were fitted with a single adjustable auxiliary air valve. The Models G and GL are water-jacketed; the

Models G, GL, L, and LL are of the vertical type, and the Models M and MR are of the horizontal type, for direct attachment to block-cast cylinders with integral intake passages. All

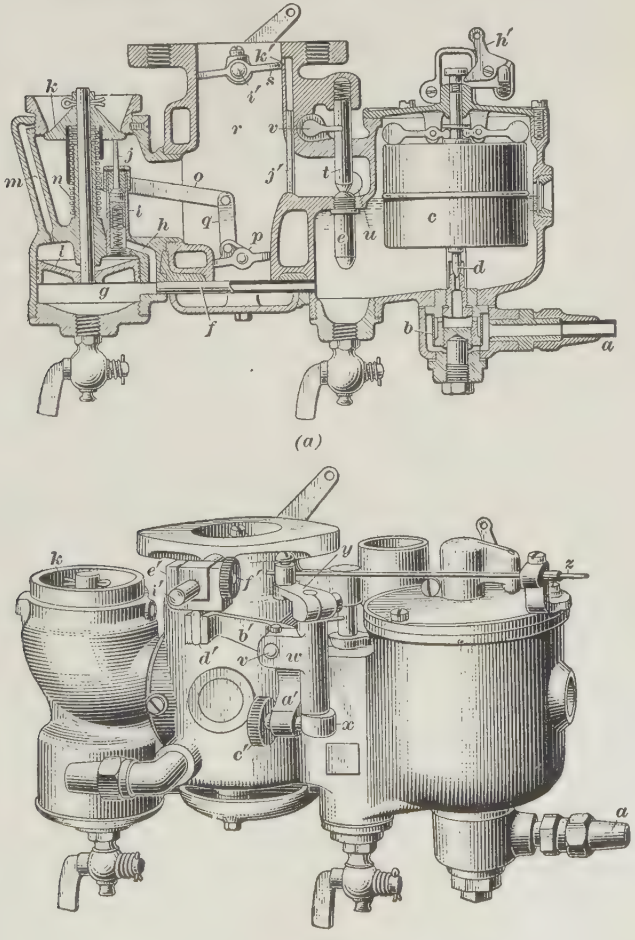


FIG. 8

of these newer model Rayfield carbureters are fitted with a secondary gasoline nozzle containing a metering pin, which comes into action only at high engine speeds.

A Model GL Rayfield carbureter is shown in section in Fig. 8 (*a*) and in perspective in (*b*); the same parts are lettered alike in both views. The fuel enters the carbureter at *a* and passes through a removable wire-gauze screen *b* into the float chamber in which the float *c* and needle valve *d* maintain a constant gasoline level. The lower end of the fixed primary spray nozzle *e* is submerged in the gasoline. A tube *f* carries the gasoline to the dashpot chamber *g*, and by way of the passage *h* to the secondary gasoline nozzle *i*, which has a variable annular opening the size of which is governed by the metering pin *j*. This metering pin moves up or down with the auxiliary valve *k*, the lower end of which carries a piston *l* loosely fitting the dashpot chamber *g*. A passage *m* connects the upper end of the dashpot chamber with the atmosphere, so that the piston *l* may freely descend with the valve *k* and force gasoline upwards into the nozzle *i*. The valve *k* is kept to its seat by the helical spring *n*. The arm *o* is rigidly fastened to the stem of the valve *k* and is connected to an arm of the butterfly valve *p* by the link *q*. In the position shown, the valve *p* closes the lower air entrance to the mixing chamber *r*, at the top of which is the butterfly throttle valve *s*.

38. The opening in the primary spray nozzle *e*, Fig. 8 (*a*), is varied by means of the needle valve *t*, which is connected to the valve *s* in such a manner that, on opening the throttle valve, the valve *t* is raised against the resistance of the helical spring acting against its upper end. The mixing chamber *r* is connected with the outside air by means of the opening *u*. The valve *t* is raised or lowered by an arm on the shaft *v*, which arm enters a slot cut in the side of the valve *t*. The shaft *v* passes through a bearing formed on the body of the carbureter, and its outer end is pinned to a movable bracket *w*, view (*b*). This bracket supports a vertical shaft, free to rotate, and having its lower end formed as an eccentric *x*. The shaft may be rotated by means of the lever *y* and the dash adjustment wire *z*.

39. Mounted loosely on the shaft *v*, Fig. 8 (*b*), is a bell-crank consisting of the arms *a'* and *b'*. The arm *d'* carries the

low-speed adjusting screw c' that bears against the eccentric x. The arm b' carries a steel tongue d' bearing against the lower edge of the steel block c', which is slanting to the left. This block may be moved longitudinally by means of the high-speed adjusting screw f'. When the screw c' is turned to the right, it forces the eccentric x and also the bracket w to the right and thus turns the shaft v so as to lift the valve t, view (a). This valve may be raised also by means of the wire z, which, when pulled, will turn the arm y and the eccentric x so as to force the bracket w away from the screw c' and thus turn the shaft v and raise the valve t.

40. Operation.—When the engine is at rest, the auxiliary valves k and p, Fig. 8 (a), are closed, as shown. To start the engine, the wire z, view (b), is pulled out, thereby turning the eccentric x and opening the valve t in the manner explained, and setting the carbureter temporarily for a rich mixture suitable for starting. If necessary, the carbureter is primed, as well, by pulling on the priming lever h', view (a), which causes gasoline to overflow from the primary nozzle e into the mixing chamber r. After the engine fires, and as soon as it has warmed up, running idly, the wire z, view (b), is pushed in, thereby dropping the valve t, view (a), and thus setting the carbureter for a leaner mixture. At idling speed, practically all the air for the combustible mixture is drawn through the air opening u; but at higher engine speeds the air valves k and p will open more and more as the speed is increased. On opening the throttle, the shaft i', view (b), will turn and tilt the block c', thus pushing down the arm b' and opening the valve t, view (a), as explained. As the valve k opens, it forces down the pin j, thereby opening the gasoline nozzle i. These nozzles and the adjacent air openings are so proportioned as to maintain a practically constant ratio of gasoline to air at all engine speeds.

41. The dashpot piston l, Fig. 8 (a), by offering a fixed resistance to the motion of the air valve k in either direction, prevents any fluttering of this valve and thereby promotes a more homogeneous mixture of gasoline and air in the mixing

chamber. The small tube j' that leads from the float chamber to the small opening k' assists in providing a rich mixture above the closed throttle while the engine is idling.

Models M and MR Rayfield carbureters have a starting primer that permits liquid gasoline to be drawn from the float chamber directly to the engine cylinders. This primer is simply a passage from the engine side of the throttle to the float chamber, which contains a valve in the form of a plunger, with a dash adjustment, the plunger closing the gasoline passage more or less, or entirely, according to the position of the dash adjustment.

42. Adjustments.—The Rayfield carbureters, Models G, GL, L, LL, M, and MR, have only a low-speed and a high-speed gasoline adjustment; in adjusting these carbureters it is well to remember that turning the adjusting screws to the right enriches the mixture and turning them to the left weakens the mixture. Also, the low-speed adjustment must be completed before the high-speed adjustment is attempted; the engine should be properly warmed up, and the dash control set for the weakest mixture.

To make the low-speed adjustment, with the throttle closed and the dash control down, the low-speed adjusting screw c', Fig. 8 (b), is turned slowly to the left until the steel tongue d' is just out of contact with the high-speed cam c'; the screw c' is then turned to the right about three complete turns. The throttle is now opened slightly, the carbureter is primed by means of the priming lever h', and the engine is started and allowed to run until thoroughly warmed up. The throttle is is then closed until with a slightly retarded spark the engine runs slowly; the low-speed adjusting screw c' is then turned slowly to the left until the engine slows down a little, and is then turned to the right, a notch at a time, until the engine idles smoothly. The idling speed is controlled by a throttle-arm stop-screw, which cannot be seen in the illustration, and which is turned to the left to lower the idling speed.

To make the high-speed adjustment, the spark is retarded fully and the throttle is quickly opened. If the engine back-

fires into the carbureter when speeded up, it shows that the mixture is too weak at high speeds, and must be enriched by turning the high-speed adjusting screw *f'* to the right, one notch at a time, until there is no sign of back-firing when the throttle is opened quickly. If the engine chokes when it is running under a heavy load with the throttle wide open, it indicates too rich a mixture, and the high-speed adjusting screw should be turned to the left until the engine begins to backfire, and then to the right again until it runs satisfactorily at high speeds.

CARBURETER, MODEL ST

43. Construction and Operation.—The Rayfield carbureter, Model ST, differs in many respects from the Model GL, shown in Fig. 8. The main features of Model ST are shown in the perspective view, Fig. 9, and in the longitudinal and transverse sections, Fig. 10 (*a*) and (*b*). In view (*a*) the float and the float chamber are partly broken away, and some of the adjoining parts are slightly displaced to show more clearly their interaction with the main nozzle. In both illustrations corresponding parts are indicated by similar letters.

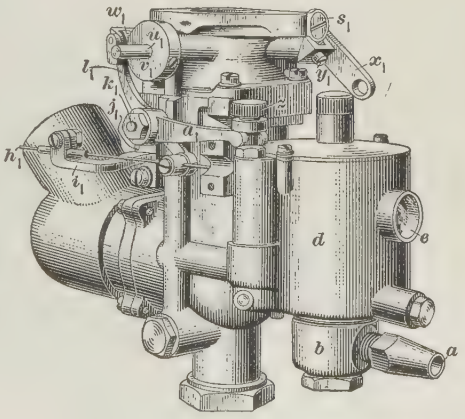
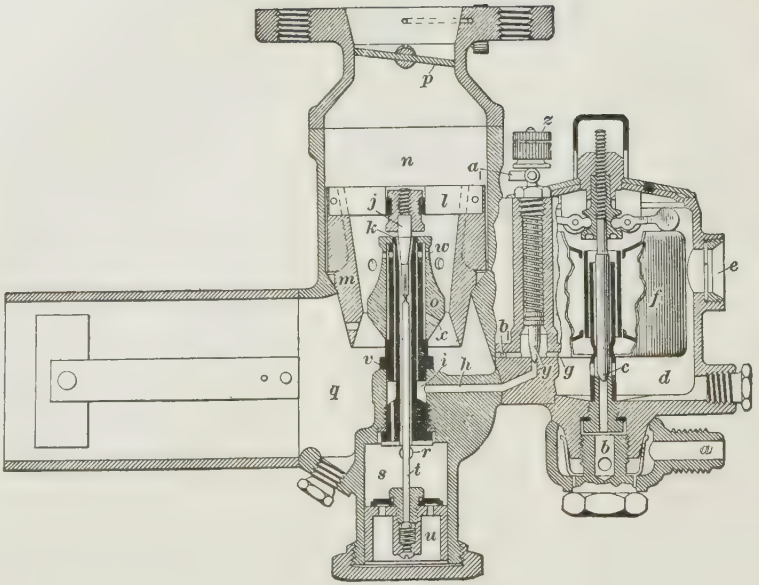


FIG. 9

The gasoline enters the carbureter at the intake *a* and passes through the strainer trap *b*, past the inlet needle *c*, into the float chamber *d*, which is provided with a window *e* through which the gasoline level may be inspected. The float *f* operates in the usual manner. The fuel passes through the ports *g* and *h* into the nozzle well *i*. In the interior of the nozzle is the metering pin *j*, which at its upper end is of a conical shape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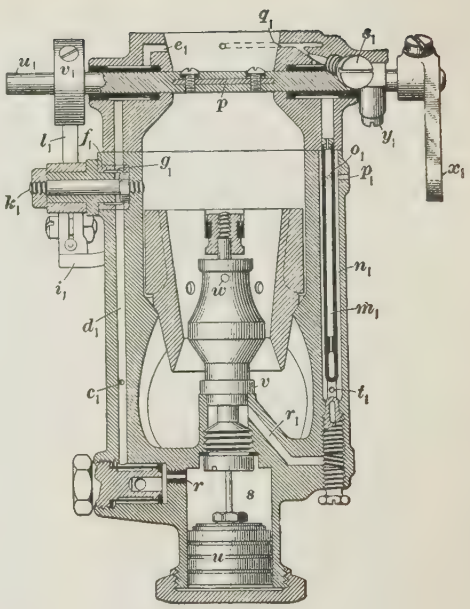
(a)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(b)

FIG. 10

to fit a corresponding conical opening in the upper end of the nozzle *k*. The pin *j* is not stationary, but is attached to the bridge *l* of the Venturi tube *m*, which may move up or down in the cylindrical mixing chamber *n*.

44. The spray nozzle *o*, Fig. 10 (*a*), may be said to consist of two truncated cones placed base to base. While the engine is idling, the widest part of the nozzle is opposite the throat of the Venturi tube; hence, at this stage the annular opening between these parts is the smallest and a minimum supply of air is allowed to pass. As the throttle *p* is opened, the resulting increase in vacuum will cause a strong current of air to enter the inlet tube *q* and flow past the nozzle *o*. The air pressure at this place will be sufficiently strong to lift the Venturi tube *m* and the pin *j* and thus permit an increased supply of gasoline to be drawn through the nozzle *k*. Simultaneously the opening between the Venturi tube and the nozzle *o* is enlarged, so that a greater supply of air will be drawn from the inlet tube *q*.

45. The supply of gasoline to the metering nozzle *k*, Fig. 10 (*a*), is permanently adjusted by means of the high-speed limit jet *r*, inserted in a passage that leads from the float chamber *d* to the dashpot *s*. The jet *r*, which is shown more clearly in view (*b*), is removable and is made in various sizes, so that the supply of fuel to the nozzle *k* can be greatly varied by a combination of changes in jets and heights of metering pin. The rod *t*, which is attached to the lower end of the pin *j*, supports the piston *u*. The latter serves to retard the motion of the Venturi tube, thus preventing it from fluttering. This piston also serves to force an increased amount of fuel through the nozzle *k* when the Venturi tube is rising and permitting a greater volume of air to pass to the engine manifold.

46. An additional supply of gasoline and air is provided by the intermediate nozzle *v*, Fig. 10 (*a*), situated between the nozzles *k* and *o*. The nozzle *v* has near its top four holes that are in line with similar holes *w* drilled through the nozzle *o*. Fuel is supplied to the nozzle *v* by the well *i*, connected by the

ports h and g with the float chamber. Simultaneously, the air, drawn through the ports x into the annular space between the nozzles o and v, passes out through the ports w and mixes with the fuel coming through the holes in the upper end of the nozzle v. The fuel that comes through the port h is controlled by the intermediate adjusting needle y, the position of which may be regulated by the adjusting screw z. An independent motion is given the needle y by the arm a_1, of which only the extreme end is shown. The complete arm is shown in Fig. 9.

47. The jet r, Fig. 10 (a), connects with a passage that opens at b_1 into a continuation of the port g. The other end of this passage is seen at c_1, view (b), where it connects with the passage d_1 leading to the strainer b, which passage is known as the *primer-fuel passage*. It has its outlet at e_1 above the throttle valve p. The amount of fuel passing through the passage d_1 is regulated by the primer valve f_1, which is a round bushing with a transverse hole g_1 of the same diameter as that of the passage d_1. The valve f_1 is operated by the dash adjustment wire h_1, Fig. 9, attached to the arm i_1 that forms part of the eccentric arm j_1, pivoted on the bolt k_1. The parts i_1 and k_1 are shown also in Fig. 10 (b). The arms a_1 and l_1, which are also connected to the arm j_1, Fig. 9, are shown separately in Fig. 10 (a) and (b), respectively. When the dash attachment at the cowl is pulled out, the arm j_1, Fig. 9, moves the needle lifter arm a_1, thus raising the needle y and increasing the fuel supply to the intermediate nozzle v.

When the dash adjustment is closed, the primer valve f_1 closes the primer passage d_1; but when the dash adjustment is pulled out beyond one-half of its travel it gradually turns the valve f_1 so that its hole g_1 will be more nearly in line with the passage d_1 until, when the dash adjustment is pulled all the way out, the passage d_1 is wide open. When the primer valve f_1 is closed, its hole g_1 lines up with an air hole drilled through the body of the carbureter, thus insuring that the primer valve will be inoperative when the dash adjustment is closed.

48. The idling fuel tube m_1, Fig. 10 (b), is inserted in a passage n_1, known as the *accelerating well* and located diametrically opposite the primer-fuel passage d_1. A hole o_1 drilled through the tube near its upper end, opposite the air bleed p_1, serves to supply air to the fuel drawn up through the tube m_1, while the throttle valve p is closed. The fuel passes out through the opening q_1 into the manifold, as a result of the vacuum existing at this place. The idling tube receives its fuel through the port r_1. The amount of fuel allowed to pass through the tube m_1 is controlled by the size of the outlet q_1, and by the adjusting screw s_1, which is also shown in Fig. 9. While the motor is idling, an excess of fuel flows into the well n_1, Fig. 10 (b), from the idling tube through the small hole t_1. As soon as the throttle is opened wide, the high vacuum existing at the main nozzle causes air at high velocity to be drawn through the nozzle o. The fuel is consequently drawn from the well into the idling tube and from the latter into the port r_1 and the well n_1 and out through the nozzle o.

49. There remains yet to be explained the interconnection between the throttle valve p, and the adjusting needle valve y, Fig. 10 (a). The throttle shaft u_1, view (b), carries a cam v_1 that actuates the roller w_1, Fig. 9, on the arm l_1. When the throttle valve shaft u_1 is turned by means of the arm x_1 the cam v_1 revolves and pushes the arm l_1 to the left, thus raising the end of the arm a_1 and lifting the needle valve y, Fig. 10 (a).

50. To start a cold engine in cold weather, the spark is partly advanced. Then the throttle is closed by moving the hand lever on the steering-wheel quadrant to the closed position. After the dash adjustment is pulled all the way out, and the starter is engaged, the engine should start quickly. As soon as the engine starts, the hand throttle lever should be advanced and the dash adjustment pushed down to its normal running position. When starting a warm engine in cold weather it will be necessary to pull the dash adjustment up only part of the way.

51. Adjustments.—In making the adjustment for idling, the throttle lever x_1, Fig. 9, is moved into the idling position,

so that the throttle valve is open very slightly, the screw y_1 being used to regulate its position. This adjustment provides a variable throttle opening for idling and at the same time a closed hand throttle; otherwise, the engine would stop when the hand throttle was closed or the foot accelerator released. The idling adjusting screw s_1 is open two full turns from its closed position, this setting being allowed to remain until the adjustment of the intermediate valve is made by means of the screw z. The stop-arm screw y_1 for the arm x_1 should also be turned a full turn to the right.

After the engine is started and is thoroughly warm, the spark is retarded and the throttle lever on the steering-wheel quadrant is moved one-eighth turn open, care being taken that the dash adjustment on the cowl is down. The screw z should then be turned to the right, a few notches at a time, until the engine shows sign of losing speed, as a result of the mixture getting lean. Then the screw z is turned to the left two or three notches until the engine runs smoothly. The extent to which the throttle is opened determines the idling speed of the engine. In making the idling adjustment, the idling speed can be regulated by means of the screw y_1. If the speed is too high, this screw is turned to the left, one or two notches at a time, until the desired speed is obtained.

SCHEBLER CARBURETERS

CARBURETER, MODEL R

52. Construction and Operation.—The Model R Schebler carbureter, built by the Wheeler-Schebler Carbureter Company, Indianapolis, Indiana, employs a single auxiliary air valve interconnected to a gasoline metering pin for obtaining a practically constant ratio of gasoline vapor to air. An external view of a Model R Schebler carbureter is shown in Fig. 11 (a), and a sectional view in (b). A constant level of gasoline is maintained in the float chamber a by the cork float b and the needle valve c, the gasoline entering at d. The gaso-

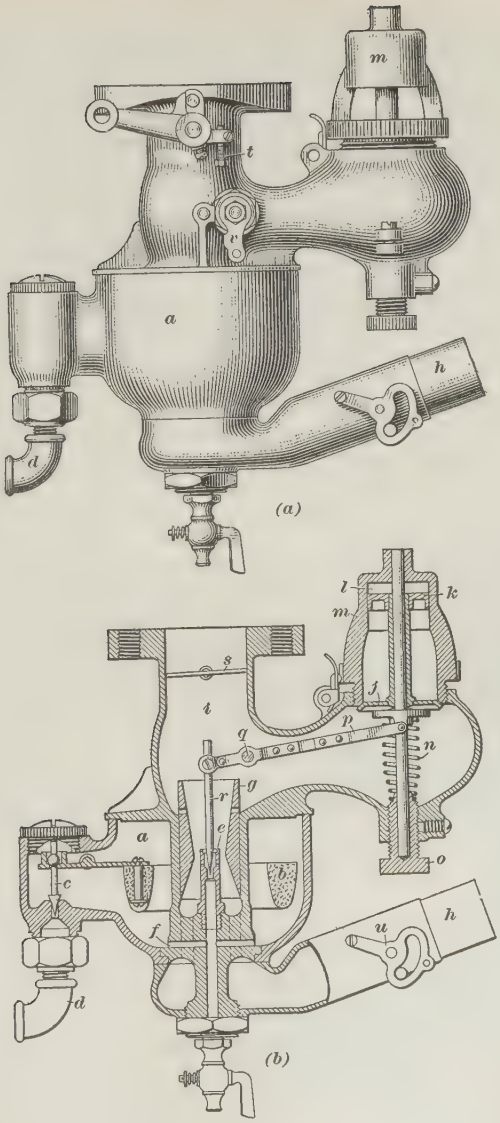

Fig. 11

line passes to the nozzle *e* through a passage *f*, the nozzle terminating at the throat of the Venturi tube *g*. The main air intake *h* is usually connected by a flexible pipe to a stove around the exhaust pipe in order to obtain preheated air. The air passes from the intake *h* through the vertical passages, indicated by dotted lines, into the base of the Venturi tube *g*, from where, after mixing with gasoline vapor, it passes into the mixing chamber *i*. At the higher engine speeds the auxiliary air valve *j* admits additional air to the mixing chamber; fluttering of the auxiliary air valve is prevented by the piston *k*, fitting loosely in a dashpot cylinder *l* formed in the auxiliary air-valve cap *m*. This air valve is held up by a helical spring *n*, the tension of which can be adjusted by the screw *o*; the air valve bears down on the long arm of the air-valve lever *p*, which is pivoted at *q* and carries at the end of its short arm the tapered metering pin *r* that enters the gasoline spray nozzle *e*.

The throttle valve *s* is fitted with a throttle-stop adjusting screw *t*, shown in view (*a*), for adjusting the idling speed of the engine; a strangling valve *u* is placed in the main air intake *h*. The pivot *q* of the air-valve lever *p* is mounted on an eccentric, carrying the cam-lever *v*, in such a manner that rocking the cam-lever will raise or lower the pivot *q*, thereby raising or lowering the metering pin *r*. The cam-lever *v* is connected by a wire to a dash or steering-post control, by the operation of which the combustible mixture can be temporarily enriched for starting and warming up the engine.

53. Adjustments.—There are two adjustments on the Models R and T Schebler carbureters, one for gasoline and one for the auxiliary air valve. The gasoline adjustment is obtained by turning the auxiliary air-valve cap *m*, Fig. 11, to the right as far as it will go, and then turning it to the left one complete turn. Next, the adjusting screw *o* is screwed in as far as it will go and then screwed out three or four complete turns. The engine is now started and allowed to run until thoroughly warmed up. Then, with the engine idling and the spark retarded, the auxiliary air-valve cap is turned to the left,

one notch at a time, until the engine fires perfectly when idling; turning the auxiliary air-valve cap to the left weakens the mixture by dropping the metering pin *r* farther into the spray nozzle *e*. This completes the gasoline adjustment.

To make the air adjustment, the spark is well advanced and the throttle opened quickly; if the engine back-fires into the carbureter, it shows that the auxiliary air valve admits too much air, and the adjusting screw *o* must be screwed in, a little at a time, until back-firing ceases. The idling speed of the engine is adjusted by means of the throttle stop-screw *i*, view (*a*). All carbureter adjustments should be made with the dash control or steering-post control set to "Lean"; the mixture can then be temporarily enriched by this control without disturbing the carbureter adjustment.

The directions here given apply when the carbureter is completely out of adjustment; slight corrections can be made by turning the auxiliary air-valve cap to the right to enrich the mixture and to the left to weaken it. The spring-adjusting screw *o* will hardly ever need to be moved when once adjusted.

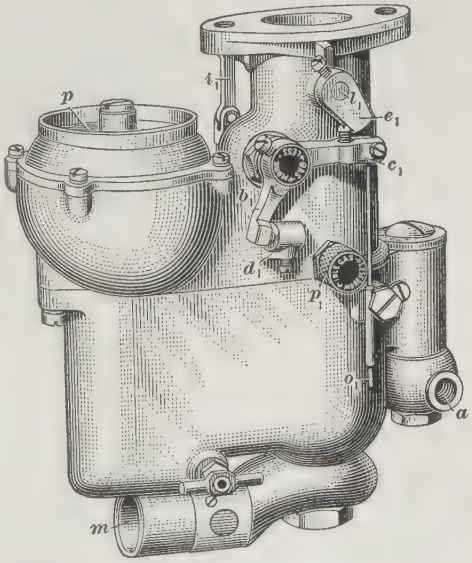

FIG. 12

CARBURETER, MODEL S

54. Construction and Operation.—The Model S Schebler carbureter also employs a single auxiliary air valve interconnected to a gasoline metering pin for obtaining a practically constant ratio of gasoline vapor to air, but the means employed differ from those used in the Model R. A perspective exter-

nal view of the Model S carbureter is shown in Fig. 12, and a longitudinal section in Fig. 13. In the latter illustration some of the parts are shown displaced and arranged in line, longitudinally, in order that their interaction may be shown more clearly.

The gasoline enters at *a*, Fig. 13, and flows through the strainer *b* and past the float valve *c* into the float chamber *d*. The float lever *e*, which has its fulcrum at *f*, is at one end

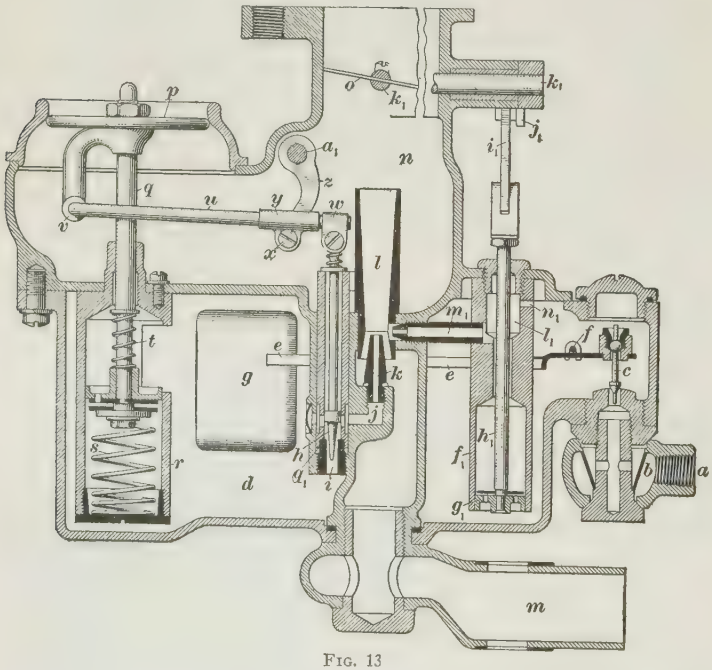

FIG. 13

attached to the float valve *c*, and at the other end to the float *g*, the latter maintaining in the usual way a constant level of the gasoline. The gasoline needle *h* controls the flow of gasoline through the passage *i* into the hole *j*, from where it flows through the nozzle *k* into the Venturi tube *l*.

55. The air intake *m*, Fig. 13, supplies air to the lower end of the Venturi tube, where, by reason of the narrow passage, the air enters at a velocity so high that even at the lowest

speeds the gasoline is picked up and thoroughly atomized. From the mixing chamber n the mixture flows past the throttle valve o into the engine manifold. The auxiliary air valve p is attached to the rod q, which at its lower end carries a piston. This piston may move down into the dashpot r against the resistance of the compressed spring s. Independent of this motion the rod q may slide down through the piston itself by compressing the light spring t, which serves to counteract any tendency of the valve to flutter. This motion comes into play also when the car is driven at a high speed and the throttle after being closed for a moment, is suddenly opened. The high vacuum produced in the manifold during the coasting period will then be transferred to the air valve, and cause the latter to descend so rapidly that only the spring t will have time to be compressed, the spring s acting simply as a momentary stop that will prevent further motion.

56. The correct fuel-to-air ratio is maintained by means of the needle-valve lift lever u, Fig. 13, pivoted at v to the air valve and at w to the needle h. The fulcrum x of this lever is not fixed, but may be shifted toward the air valve, as the loose sleeve y is moved to the left by the turning of the fulcrum lever z. This lever is attached to the shaft a_1, which at its outer end carries the dash control lever, the arms b_1 and c_1 of which are shown in Fig. 12. When the throttle valve is shut, the arm b_1 makes contact with the stop d_1. It follows also that the fulcrum lever z cannot move to the right beyond the position it occupies in Fig. 13. As the throttle valve begins to open, the cam e_1, Fig. 12, will move to the left and force the arm c_1 down, thereby turning the shaft a_1, Fig. 13, clockwise. This action will move the sleeve y to the left and upwards, thus raising the needle h and admitting more gasoline to the nozzle l. If at this stage the valve p is depressed, a greater quantity of gasoline will be admitted, because the lever arm $x\,w$ has increased in length relative to the arm $x\,v$.

57. The accelerating pump f_1, Fig. 13, serves the purpose of quickly enriching the mixture when the throttle is opened

suddenly. The pump contains the piston g_1, which by means of the rod h_1 and the link i_1 is connected to the throttle lever j_1 fastened to one end of the throttle shaft k_1. When the throttle is opened, the piston g_1 is raised and gasoline is forced into the upper chamber l_1, from where it flows through the passage m_1 into the Venturi tube. As more gasoline is transferred to the chamber l_1 than is actually required, the overflow n_1 is provided, so that the surplus may flow back into the float chamber.

The Model S carbureter has no choke valve; it delivers to the engine whatever air is required, and meters the corresponding amount of fuel into the air. When a very rich mixture is needed, as in starting a cold engine, the dash control arm c_1, Fig. 12, is pulled down by means of the wire o_1. This will rotate the lever z, Fig. 13, to the left and give the needle h an initial lift and an increased motion relative to that of the air valve. The rich mixture that is then being supplied to the engine is maintained at the proper ratio of gasoline and air for all speeds. As the engine is warming up, the dashboard control is gradually pushed in, which in turn raises the control lever c_1, Fig. 12, and moves the fulcrum x, Fig. 13, to the left, thus adjusting the mixture to the different degrees of temperature of the engine during the warming-up period, until finally when the engine has reached its running temperature, the dashboard control is pushed entirely in, and the mixture of air and gasoline is back to normal.

58. Adjustments.—The carbureter shown in Fig. 12 may be adjusted at four places, but as three of the adjustments are made at the factory, only one, the idling adjustment, need be made by the owner or the garage mechanic. This adjustment is made by turning the screw p_1, Fig. 12, which will revolve the valve seat q_1, Fig. 13, thus causing it to be raised or lowered. By raising or lowering this seat, the mixture is made leaner or richer, respectively. While the engine is idling with a retarded spark, the air valve p should be opened from $\frac{1}{32}$ to $\frac{1}{16}$ inch. If the engine then starts to cut out or miss explosions, the idling mixture is about right. If it is too lean,

the engine will stop when the valve is opened as described; if too rich, the valve will have to be moved a considerable distance before the engine cuts out.

MILLER CARBURETERS

59. Construction and Operation.—The Miller carbureters are made by the Harry A. Miller Manufacturing Company, Los Angeles, California. The distinctive feature of these carbureters is found in the application of a series of gasoline jets, instead of only one as in most of the other types of carbureters. It is claimed that, by an increase in the number of jets, the fuel is measured out in small fixed quantities that are

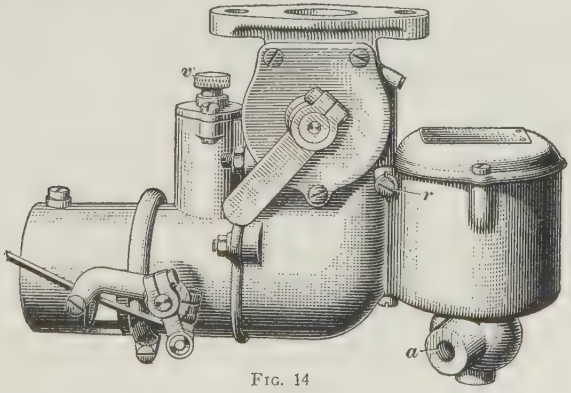

FIG. 14

more completely vaporized; the more so, as the fuel delivered to the jets is already partly mixed with air.

Of the several Miller carbureter models, only Model H will be described, of which an external view is shown in Fig. 14. In Fig. 15 (*a*) is shown a longitudinal section of the carbureter, supposed to have been turned end for end. The fuel-line connection is at *a*, from where the fuel passes through the screen trap *b*. The gasoline enters the float chamber through the float valve *c* and is maintained at a constant level by the float *d*. The fuel leaves the float chamber through the passage *e*, which connects with the jet tubes *f*, of which there are six in this case.

60. Air enters through the choke chamber *g*, Fig. 15 (*a*), where the incoming current is regulated by the choke valve *h*, the current continuing through the passage *i*, which is closed

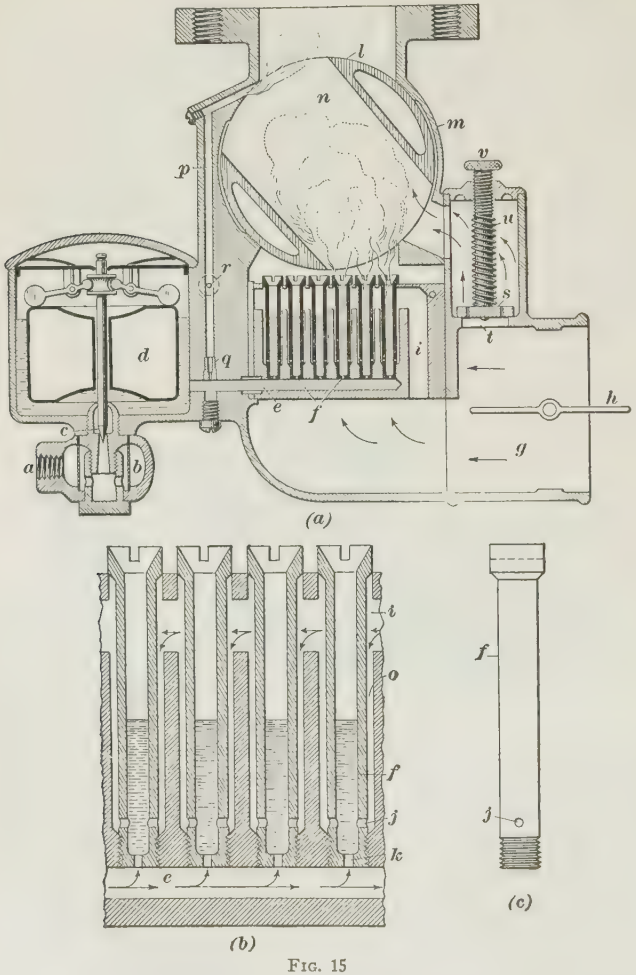

FIG. 15

at its left-hand end, but connects with the wells, or jackets, that surround the jet tubes. The air enters these tubes through small holes located near the lower ends of the tubes. This arrangement is shown more clearly in the enlarged detail,

view (*b*). An exterior view of one of the tubes *f* is shown in view (*c*), the air opening near the bottom being shown at *j*. The tubes are inserted in a metal box, known as the *magazine*, which may be detached, as a whole, from the carbureter, if any one tube is to be examined or replaced. The gasoline flows in the direction of the arrows through the passage *e* and on entering the interior of each tube through the bottom orifice *k*, view (*b*), rises to a level corresponding to that of the gasoline in the float chamber.

61. The barrel-shaped throttle *l*, Fig. 15 (*a*), which may revolve in the cylindrical chamber *m*, has an opening *n*. When the throttle is revolving into its open position, this opening will gradually uncover the tops of the jet tubes *f* and subject them to the action of the vacuum existing in the engine manifold. View (*a*) shows three tubes in operation and sending a mixture into the throttle opening. It is seen that the first three tubes from the left are still filled with gasoline, as they are not yet exposed to the vacuum existing in the throttle. When the throttle valve begins to open, air passes into the channel *i*, view (*b*), and down through the wells *o* surrounding the tubes. When the throttle is fully open, the vacuum to which each tube is subjected will cause air to flow down into each of the wells *o* and then through the orifices *j* into the tube interiors, where it will mix with the gasoline drawn up to the tops of the tubes. At this place the fuel mixture meets the air-currents that ascend on each side of the tube magazine. The mixture will undergo a further vaporization as it passes through the throttle and into the engine manifold.

62. Adjustments.—The idling port *p*, Fig. 15 (*a*), which at its upper end opens into the mixing chamber above the throttle, has at its lower end the idling jet *q*. At *r* is an adjustable air valve by which the air admitted at this point may be regulated. The auxiliary valve *s* closes the opening *t* through which air may be admitted when the engine is running above idling speed. The valve is forced to its seat by the spring *u*, the pressure of which may be regulated by the intermediate adjusting screw *v*.

FORD CARBURETERS

63. Construction.—The Model X Ford carbureter, built by the Ford Motor Company, Detroit, Michigan, has a single air inlet and a single air valve. This carbureter is shown in longitudinal section in Fig. 16 (*a*), and an end view, partly broken away, is shown in view (*b*). The gasoline enters the float chamber *a* through the connection *b* and is maintained at a constant level by means of the needle valve *c* and the metal float *d*. The air inlet *e* is fitted with a choke valve *f* and is supplied with preheated air. The air flows through the V-shaped Venturi tube *g* and out through the opening *h*, closed at times by the flat valve *i*, which is pivoted on the pin *i'*. The upward motion of this valve is limited by the cushioned stop *j*.

64. The gasoline nozzle *k*, Fig. 16 (*a*), connected at *k'* with the float chamber, is controlled by the needle valve *l*, which extends through the center of the idling tube *m*. The upper end of the nozzle *k* is slightly below the level of the gasoline in the float chamber while the engine is running. The port *n*, which opens to the atmosphere at its lower end, is provided at its upper end with a nozzle *o* that terminates slightly above the gasoline level. This port serves simply as an overflow in case of an excessive accumulation of gasoline in the Venturi tube while the engine is at rest; it does not affect the air supply of the carbureter. The shaft of the throttle *p* has two arms *q* and *q'*, the arm *q* connecting with the throttle lever on the steering wheel and the arm *q'* being fitted with a stop-screw *r* that engages with the stop *s*, both arms being limited in their motion by this stop. The drain cock *t* with the opening *t'* serves to empty the float chamber of water and sediment, when necessary. The vent *u* allows air to enter the top of the mixing chamber.

65. Operation.—While the engine is at rest, the condition of the carbureter, Fig. 16, is as follows: There is a puddle of gasoline covering the bottom of the Venturi tube *g*, thus sealing the lower end of the idling tube *m*. The flat valve *i* is resting on its seat. On cranking the engine, the gasoline in

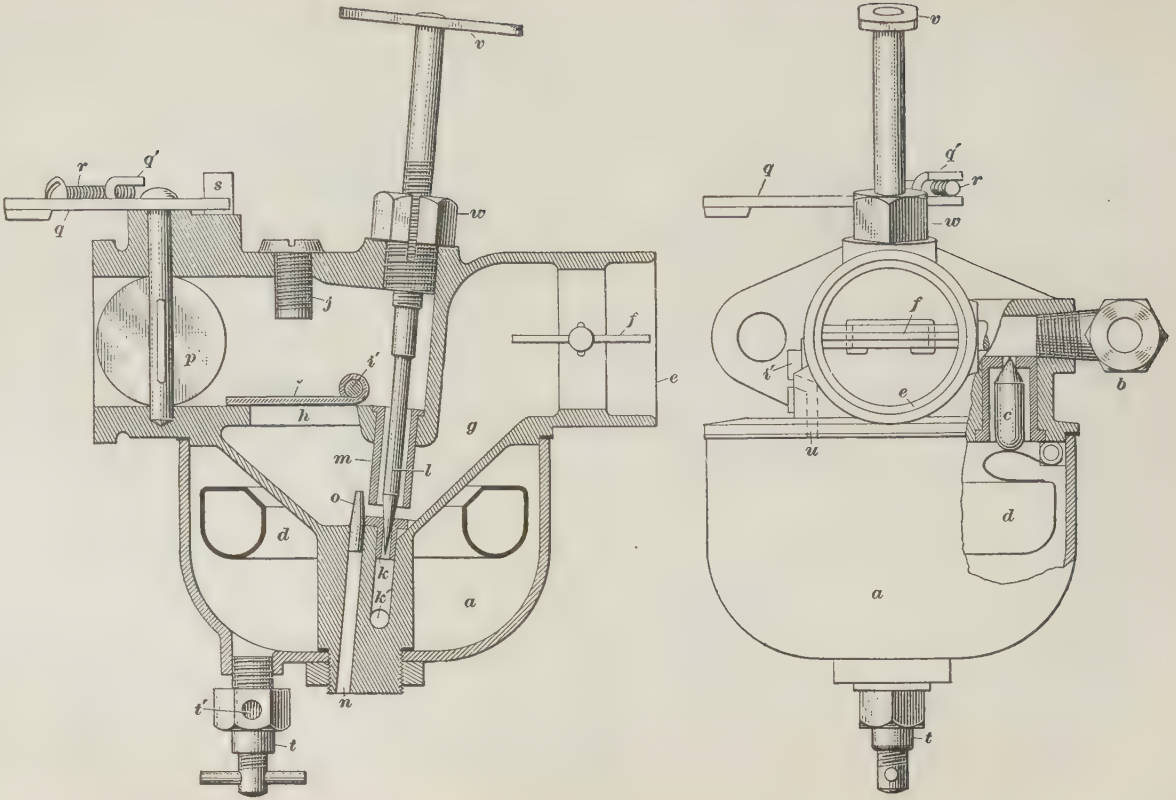

FIG. 16

the puddle is gradually drawn up into the tube *m* until its lower end is uncovered. Air will then enter the tube and mix with the gasoline issuing from the nozzle *k* to form a rich mixture for easy starting. As soon as the engine fires and is running at low speed, all the explosive mixture passes through the idling tube *m*. The air, as it passes from the Venturi tube *g* into the tube *m*, will sweep over the mouth of the nozzle *k* and pick up sufficient gasoline to form an explosive mixture. When the engine is speeded up, the air valve *i* begins to leave its seat, thus permitting the mixture to pass through the opening *h* as well as through the tube *m*. The valve *i* will rise higher and higher as the engine speed increases, more air will pass through the whole of the Venturi tube *g* with an increasing velocity, and will pick up enough fuel from the nozzle *k* to maintain a practically constant ratio of fuel to air at all engine speeds.

66. Adjustments.—The only part of the carbureter, Fig. 16, that requires adjustment is the needle valve *l*, which may be turned by the handle *v* after the split locknut *w* has been loosened. If the carbureter is completely out of adjustment, the valve handle *v* is first turned to the right until the valve seats lightly, and then to the left one complete revolution. The engine is then started and allowed to run until completely warmed up. Next, the idling speed is adjusted by closing the throttle and adjusting the throttle stop-screw *r*. With the engine idling, the handle *v* is turned to the right, a little at a time, until the engine slows down, thus indicating a weak mixture; the handle *v* is then turned to the left again very slowly until the engine runs strong. If upon opening the throttle quickly the engine does not respond at once, it indicates a slightly weak mixture, and the handle *v* must be turned a little more to the left. When this adjustment is completed, the locknut *w* should be tightened to prevent the position of the handle *v* from being accidentally changed.

CARTER CARBURETERS

67. Construction of Model O Carbureter.—The Carter carbureters are manufactured by the Carter Carbureter Cor-

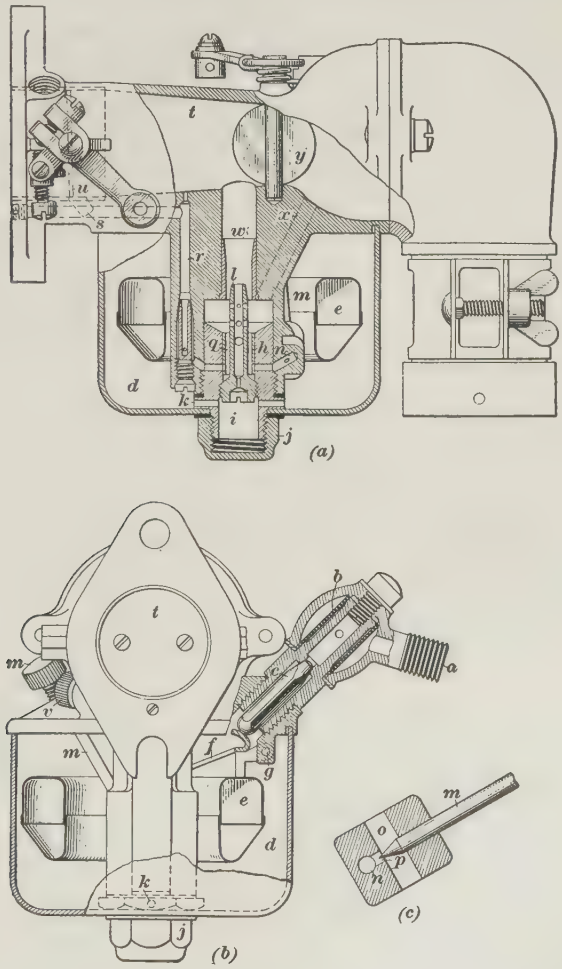

FIG. 17

poration, St. Louis, Missouri. An example of a horizontal Carter Model O carbureter is shown in Fig. 17, in which

view (*a*) is a side view, partly broken away to show the interior construction, and view (*b*) an end view that shows the float, the bowl, and the gasoline intake needle in section. The carbureter operates automatically; it is without springs or air valves, and is adjusted before it leaves the factory. The gasoline enters at the connection *a*, view (*b*), and flows through the strainer *b* and past the needle valve *c* into the bowl *d*. Here the float *e* maintains a constant level by means of the float lever *f* and the needle valve *c*. This lever, which is of a semicircular shape, is pivoted at *g* and has a short arm that pushes the valve to its seat. When the float reaches its highest position its top should be $\frac{1}{2}$ inch below the carbureter body. The approximately cylindrical portion of the carbureter body that projects down into the bowl *d*, view (*a*), contains the various devices for feeding and atomizing the gasoline. The lower end of the part *h* contains a cavity *i* (known as the *well*) and projects through a central hole in the bowl *d*. This end is provided with a nut *j* by which the edge of the bowl is forced into a circular groove formed in the carbureter body.

68. Operation.—The gasoline flows through the orifices *k*, Fig. 17 (*a*), into the cavity *i* of the well and from there into the axial hole of the multiple-jet nozzle *l*, which is provided with a series of holes, as shown. The supply of gasoline to the well is regulated by the high-speed adjusting screw and the needle *m*, view (*b*). The lower part of this needle is shown also in view (*a*), as well as the port *n* through which gasoline flows into the axial well surrounding the nozzle *l*. The diagrammatic cross-section, view (*c*), shows the general arrangement of the needle *m* relative to the port *n*. The recess *o* allows gasoline to enter the hole *p* that communicates with the port *n*. As the needle *m* is screwed down or up, the opening of the hole *p* is decreased or increased, respectively.

The well *q*, view (*a*), leads to the low-speed passage *r*, which connects through the port *s* with the mixing chamber *t*, the port being situated just inside the closed throttle *u*. By means of the low-speed adjusting screw *v*, view (*b*), the opening of the port *s* may be adjusted to give the proper idling speed.

69. When the engine is running, the vacuum produced in the mixing chamber *t*, Fig. 17 (*a*), causes a stream of gasoline to pass out through the nozzle *l* into the Venturi tube *w*, and out into the mixing chamber, and then past the throttle valve *u* to the engine. Air is drawn into the well *h* through the hole *x*, shown by dotted lines. If the presence of dirt in any one of the jets should cause a loss of power or uneven running, it is often possible to clean the jets by choking the carbureter by means of the choker valve *y*. It is best to do this when the car is running in high gear at 25 miles an hour. First the throttle valve *u* is opened wide and the carbureter choke-rod button is pulled out as far as possible and held in that position for two or three seconds. Then the choke-rod button is pushed back and the throttle is gradually closed as the engine begins firing again.

FRANKLIN CARBURETERS

70. Construction and Operation of Carbureter Proper. The carbureters used on Series 10 Franklin cars are manufactured by the Franklin Automobile Company, Syracuse, New York. At present there are two carbureter models, differing slightly in construction, in use on the Series 10 cars. Of these models only the more modern one will be described, though attention will be called to the essential features that differ in the two models.

A perspective view of the complete carbureter is shown in Fig. 18. It is seen that some of the component parts are distributed at various points around the main body. The arrangement of the interior parts is likewise more or less unsymmetrical. It follows that in order to show the interaction between the principal parts, a number of separate cross-sections would be required. As even such sections would fail to give a clear idea of the principle of operation of this carbureter, it is preferable to give a diagrammatic longitudinal section, as in Fig. 19 (*a*), in which the principal parts are shown removed from their true positions and arranged along the center line of the carbureter. In the side view (*b*), the parts that belong to the

electric vaporizer are shown in section, so as to disclose their interior construction and arrangement. In Figs. 18 and 19 similar parts are indicated by similar letters, thus facilitating comparison of the various views.

71. The carbureter shown in Fig. 18 is of the single-jet type and has a main air valve that, in conjunction with an auxiliary valve, maintains a correct mixture at all engine speeds and throttle positions. In addition, provision is made for heating and vaporizing by electrical means an auxiliary combustible mixture that is to be used for starting the engine in cold weather.

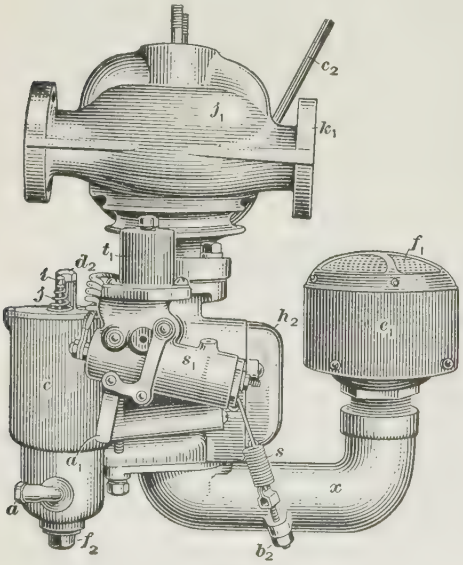

FIG. 18

The gasoline, after entering the carbureter through the connection *a*, Fig. 19 (*a*), passes through the wire-gauze strainer *b* to the float chamber *c*, where it is maintained at a constant level by the brass float *d* and the needle valve *e*. Gasoline flows to the spray nozzle *f* through the port *g*, the supply being regulated by the needle valve *h*, which may be operated from the dash. For the purpose of priming, the nozzle *f* may be supplied with an increased amount of fuel by pushing down the priming button *i*, thus depressing the float *d* and causing the fuel to overflow through the nozzle *f*. When released, the button *i* is returned by the spring *j* to its former position.

72. Since the velocity of the air-current passing through the choke of the Venturi tube *k*, Fig. 19 (*a*), would not be sufficiently great to draw the proper amount of fuel from the

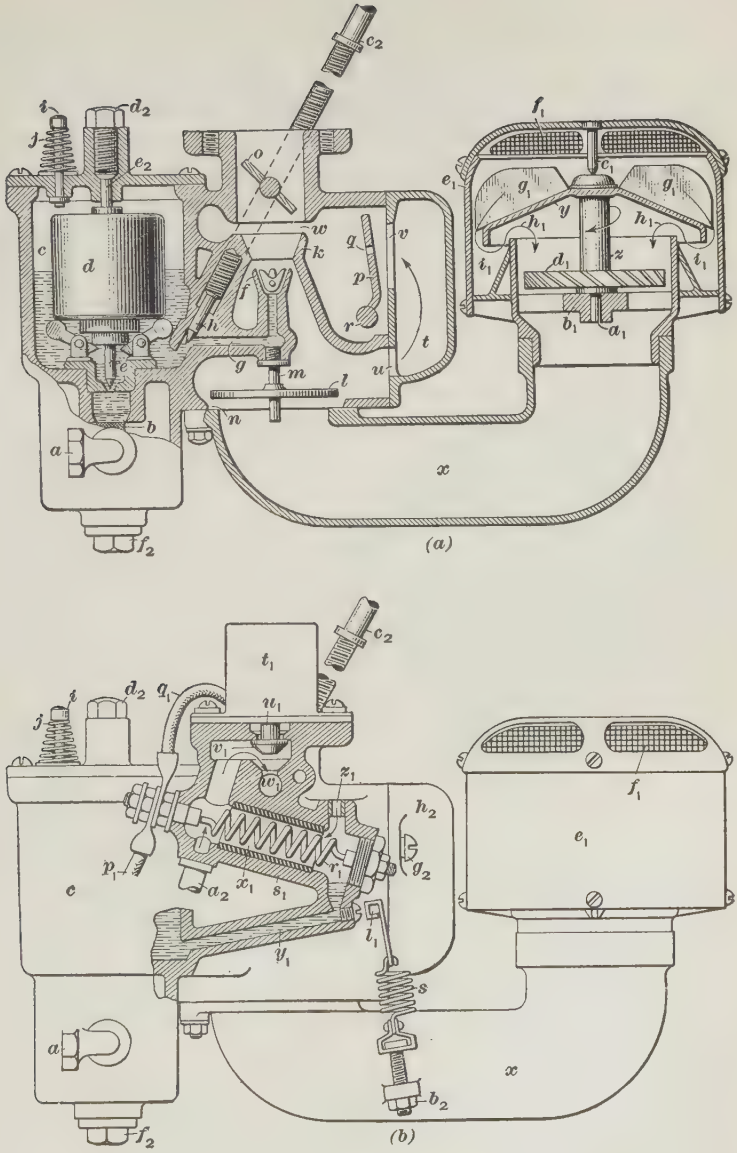

FIG. 19

nozzle *f*, the air supply is restricted by means of the metal disk *l*, arranged to slide up and down on the pin *m*. This disk is provided with a number of holes of such a diameter that a definite amount of air may pass through to mix with the fuel issuing from the nozzle. By restricting the air supply in this manner, the vacuum existing in the inlet manifold will be enabled to lower the air pressure in the Venturi tube, and thus cause an increased amount of fuel to be drawn from the spray nozzle. When the engine begins to operate, the disk *l* is resting on its seat *n* and the air required for the fuel mixture is admitted only through the disk perforations. As the throttle *o* is opened wider, the vacuum in the Venturi tube will increase, until shortly the disk *l* is lifted from its seat. The air-current passing the nozzle *f* is now strong enough to extract from it a sufficient amount of fuel.

73. As the throttle *o*, Fig. 19 (*a*), is opened more and more, the disk *l* will eventually reach its highest position, and the amount of air passing through the Venturi tube will finally be insufficient to provide a correct mixture for the engine. At this stage the auxiliary flap valve *p* begins to operate. This valve is shown partly open, but even in its closed position it allows a limited amount of air to pass through the $\frac{5}{16}$-inch hole *q*. The valve is pivoted on the shaft *r*, and the helical spring *s*, Fig. 18, tends to keep the valve in a closed position. When the valve *p*, Fig. 19 (*a*), begins to open, as a result of opening the throttle wider, air will enter the chamber *t* through the port *u* and leave it through the port *v*. Subsequently this air-current will pass through the annular orifice *w* and unite with the current coming through the Venturi tube. After the throttle valve is moved into its fully opened position, the flap valve will be opened wide and thus maintain the proper mixture of gasoline and air.

74. Before the outside air is allowed to enter the Venturi tube through the inlet tube *x*, Fig. 19 (*a*), it must pass through an air strainer located at the open end of the tube. The strainer consists of a cone *y*, provided with a hollow shaft *z* that at the lower end has a journal a_1 resting in the bearing b_1.

The upper end is held in place by the pin c_1. The inclined vanes d_1, fastened to the lower end of the shaft, constitute a fan, which, when subjected to the action of the descending air-current, will cause the shaft z and the cone y to revolve in the direction of the arrow on the shaft z. The current of outside air that enters the hood e_1 through the screen f_1 is impelled against the quickly revolving cone y, which, by means of the radial vanes g_1, whirls the air around and throws it against the inner wall of the hood e_1. By reason of the low air pressure prevailing in the tube x, the air is compelled to follow the path indicated by the arrows h_1 and pass into the interior of the cone y. The fine, solid particles contained in the air will, by reason of the centrifugal force acting on them, be thrown against the walls of the hood e_1 from where they fall down through the orifice i_1, located outside the tube x.

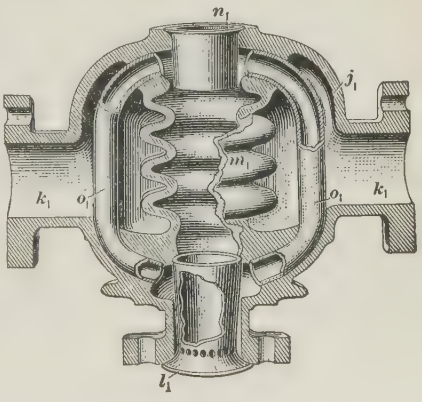

FIG. 20

75. Action of Gas Heater.—When the gaseous mixture leaves the throttle chamber, it is sent through the gas heater j_1, Fig. 18, in order that any unvaporized gasoline may be reatomized before entering the cylinders. The action of the heater will be explained by means of Fig. 20, which shows the engine exhaust tube k_1 in longitudinal section, and some of the heater tubes partly broken away. The gaseous mixture passes successively through the lower sleeve l_1, the corrugated cylinder m_1, and the upper sleeve n_1 into the engine inlet manifold. The corrugated cylinder m_1 is heated by the exhaust gases passing through the pipe k_1, and therefore, assists in vaporizing the gaseous mixture. The unvaporized gasoline will adhere to the inside surface of the cylinder m_1 and creep upwards until it reaches the top, when it will enter the two tubes o_1 and pass downwards into the

sleeve l_1 through the row of holes drilled near its lower edge. Here the gasoline is reatomized and thrown into the center of the stream of combustible mixture.

76. Action of Electric Primer.—When the primer switch on the dash is raised, an electric current will be sent through the wires p_1 and q_1, Fig. 19 (b), into the coil r_1 of the electric vaporizer s_1 and into a solenoid enclosed by the casing t_1. This solenoid operates the stem u_1 of the vaporizer valve v_1, lifting the latter and thus opening the port w_1 that leads to the inlet manifold. The vacuum existing in the latter place will be transmitted to the vaporizer chamber x_1 and cause fuel to be drawn from the passage y_1. This fuel, after mixing with the air drawn in through the primary air inlet z_1, passes over the hot coil r_1, which converts it into a dry, highly explosive gas. Before this gas is allowed to pass through the port w_1 to the manifold, it is mixed with additional air drawn through the auxiliary air intake a_2. Earlier Series 10 models have in the tube x a choke valve that is operated by a separate electromagnet, situated near the air strainer e_1. When the electric primer is in operation, the current that flows through this electromagnet will cause the choke valve to close and thus increase the vacuum in the coil chamber x_1.

77. Adjustments.—A faulty adjustment of the auxiliary air valve p, Fig. 19 (a), will affect the operation of the car, causing the engine to start hard or to load with an excess of gasoline. It may result in loss of power, or, in case the throttle is suddenly opened, produce a decrease instead of an increase in speed. The tension of the valve spring s, Fig. 18, should be just enough to hold the valve to its seat when the engine is not running. The adjusting screw b_2 should be turned in the required direction to effect this result. If the needle-valve rod c_2 works too easily, the clamp screws on the front of the dash should be tightened. Or, the spring situated at the place where the valve rod enters the carbureter may have its tension increased by the addition of a couple of washers. In case the valve rod binds, the parts should be oiled and the clamps loosened.

Sometimes it is found that the carbureter needle-valve pointer at the dash panel has been displaced. It may be reset in the following manner: After the pointer is loosened, the engine is set running at a moderate speed; then the needle valve is turned to the right and to the left, until a point is found at which the engine runs at its best. At this point the needle valve should be open about one-half turn. Leaving the valve rod in this position, the pointer is set at the center of "Run" and fastened with the small setscrew. The valve may be turned from this position into such a one as will produce either a lean or a rich mixture.

78. In case the primer valve v_1, Fig. 19 (b), should stick in its open position, it will cause the engine to load up and result in a very poorly running motor. A slight tap on the side of the casing t_1 will usually make the valve drop to its seat. Otherwise, the valve must be removed to have its stem polished with emery cloth; but care must be taken to remove all emery from the valve and any dirt or iron filings from the interior of the solenoid. To test for leakage at this valve, the needle valve h, Fig. 19 (a), should be closed, and the attempt made to run the engine by gradually opening the hand throttle while the ignition is on and the starter is turning the engine over. The engine will fail to start if the primer valve is tight. If a leaky float valve causes the carbureter to flood, the guide screw d_2 must be removed and a small screwdriver inserted in the slotted end of the valve stem e_2. Then, while a slight downward pressure is exerted, the valve is rotated several times to remove any foreign material and thus allow the valve to reseat itself. A flooded carbureter may also be caused by a leaky float or a bent valve stem.

79. Cleaning of Carbureter.—The carbureter should be cleaned after a run of 3,000 miles. Usually, it is sufficient to remove the screen b, Fig. 19 (a), by unscrewing the plug f_2 to which the screen is attached. The screen is to be cleaned with clean gasoline, care being taken not to injure the fine wire mesh, and to screw the plug on tight when it is replaced. If compressed air is available, the whole carbureter should be

cleaned. For this purpose the gasoline is drained from the vacuum tank and from the carbureter. Then the strainer plug f_2 is removed and also the machine screws g_2, view (b), in order that the chamber h_2 may be removed. After closing the needle valve h, view (a), the atomizer is cleaned by blowing air through the rear port u. Then the needle valve is opened several turns and air is again blown through the passage to clean the opening that leads to the float chamber. The passage y_1, view (b), should be cleaned by blowing air through the small hole z_1. Finally, the float-chamber cover is removed and any dirt is blown out that may have collected in the chamber. All removed parts must be carefully replaced.

PIERCE CARBURETERS

80. Construction and Operation.—The Pierce carbureters, manufactured by the Pierce-Arrow Motor Car Company, Buffalo, New York, are used on the Pierce-Arrow motor cars, Models 32 and 33. These carbureters are similar in design and operation to the carbureters employed on earlier models of these cars. In Fig. 21 (a) is shown a side view of the carbureter, and in view (b) a longitudinal section. The gasoline is forced by air pressure from the gasoline tank through a pipe, connected with the coupling a, into the strainer case b, and from there into the float chamber c, where the needle valve d, in conjunction with the float e, maintains the gasoline level at a constant height. This level should be at the groove formed in the little post f, located inside the window g through which the post may be seen. The gasoline flows through the port h into the chamber i, which is closed at its lower end by the plug j. In the upper end of this chamber there is an idler nozzle k that opens into the passage l leading to the port m. When the throttle n is closed, as shown, the port m is nearly fully covered by the throttle, the uncovered portion of the opening being partly closed by the adjusting screw o. While the engine is idling, the explosive mixture is compounded of gasoline drawn from the nozzle k and air entering through the port p.

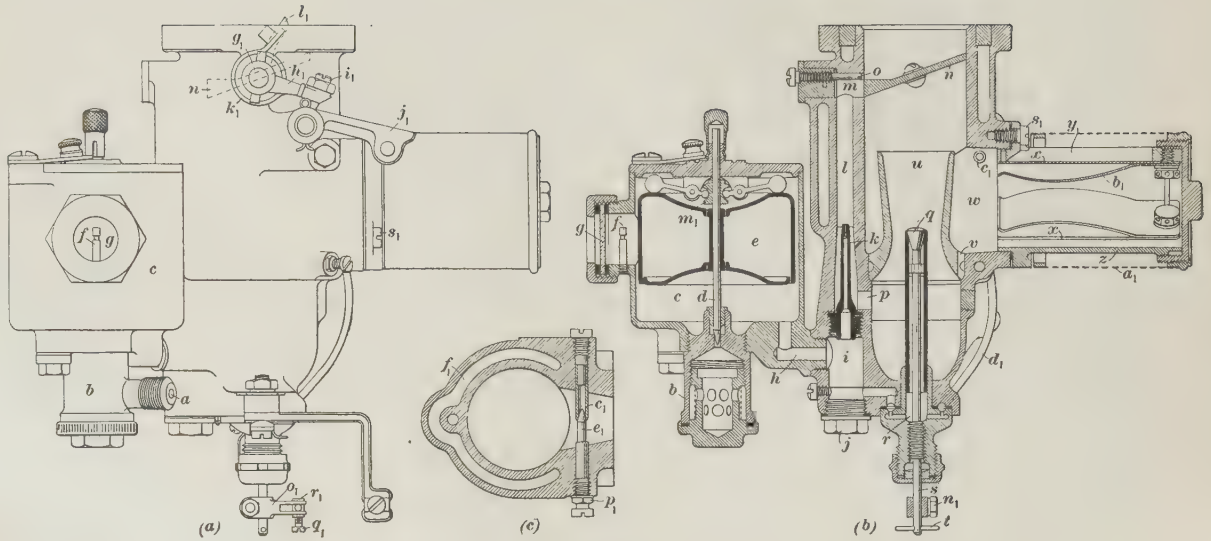

FIG. 21

81. When the throttle n, Fig. 21 (b), is opened a little beyond its idling position, the vacuum in the passage l will increase for a little while and will then become equal to that existing below the throttle. At this stage the spray nozzle q comes into action. This nozzle, which derives its fuel from the well r, connecting with the chamber i, is regulated by the needle s, provided at its lower end with a handle t. When the fuel leaves the nozzle q and passes into the Venturi tube u it combines with air drawn through the port v from the air chamber w. As soon as the throttle n is opened enough to bring the nozzle q into action, the idling nozzle k will cease to operate:

82. Air is supplied to the chamber w, Fig. 21 (b), through the auxiliary reed valves x, of which there are three, the operating reeds being known as the light, the intermediate, and the heavy reed, respectively. These reeds close narrow, rectangular openings y formed in the cylindrical casing z, which is enclosed in an air-filter screen a_1. To the inner side of each reed there is fastened a spring b_1 bent in such a way as to give each reed a definite amount of deflection, when fully opened.

As the reeds vary in thickness, it follows that their flexibility will decrease with an increase in thickness. Hence, the thinnest reed will be the first to respond to a decrease in air pressure in the chamber w, and will bend inwards to admit outside air. As the engine speeds up, one reed after another will come into action and admit more and more air, until each reed is in contact with its spring b_1 and admitting a maximum amount of air to the chamber w.

83. When the engine is running at high speed, the vacuum in the chamber w, Fig. 21 (b), is sufficiently high to bring into action the high-speed nozzle c_1, more fully shown in the cross-section, view (c). This nozzle is supplied with gasoline by the tube d_1, view (b), which connects with the well r. The opening of the nozzle c_1 is regulated by means of the needle e_1, view (c). In the cross-section is shown also the chamber f_1 surrounding the main body of the carbureter, and through which the exhaust gases are passed for the purpose of heating the throttle or mixing chamber.

84. In the inlet manifold there is a small valve that is operated from the dash. When the valve is opened, the vacuum in the manifold will cause a spray of gasoline to issue from the valve and produce a mixture that will enable the engine to start during cold weather. This primer valve, which receives its fuel from a tube connected with the well *r*, Fig. 21 (*b*), functions independently of the carbureter.

85. The throttle valve *n*, Fig. 21 (*a*), is fastened to the shaft g_1, which at each end projects through the throttle chamber. To the shaft end is attached a lever h_1 that carries a screw i_1 by means of which the throttle valve may be adjusted into its correct idling position. The lower end of this screw is forced against the lever j_1 by the helical spring k_1 attached to the shaft g_1. The other end of this shaft carries the lever l_1 by which the shaft may be turned into its open position. The lever j_1 is connected to a rod leading to the dash, and is used in priming the engine.

86. Rules to Be Observed.—All units by which the carbureter is held to the manifold must be screwed down tight; otherwise, there may be air leakage between these parts. Periodically, the strainer case *b*, Fig. 21 (*a*), should be removed and any sediment washed off that may have collected in the float chamber. Also, the plug *j* should be unscrewed and the idling nozzle *k* cleaned by applying compressed air to the well *i*. The height of the gasoline level in the float chamber should be checked. When the car is on level ground and the engine is not running, the level should be up to the groove cut in the post *f*. This level is adjusted at the factory; but if it is found necessary to alter it, the best method is to change the position of the sleeve m_1 by unsoldering the joint made with the needle valve *d*.

The screen of the cold-air regulator in the carbureter hot-air stove should be cleaned and adjusted according to the weather in the following manner: (*a*) In cold weather both screens should be closed. (*b*) In warm weather the rear screen may be open and the front screen closed. (*c*) In extremely hot weather both screens should be open or off.

87. Preliminary Adjustments.—To adjust the throttle valve *n*, Fig. 21, into its correct idling position, the throttle lever on the steering column should be moved fully into its retard position, so as to close the throttle valve. Then the locknut on the screw i_1, view (*a*), is loosened and the screw is backed off until it barely touches the lever j_1. Then the screw is turned to the right from three-quarters to a full turn, and the locknut is fastened in place. The idling screw *o* is adjusted into its correct position by first screwing it far enough to seat its shoulder, and then backing it out from one and one-quarter to one and three-quarters turns.

Before the main needle *s* may be adjusted, it is necessary to loosen the capscrew n_1 that clamps the lever o_1 to the needle. The latter is then turned to the left until it seats, and then from five-eighths to three-quarters of a turn to the right. The locknut p_1, view (*c*), must be loosened before the high-speed needle e_1 can be adjusted. By use of the fingers, the needle is first *carefully* turned into its seat; then, it is unscrewed from one-fourth to one-half turn and held in place with a screwdriver while the nut is being locked.

88. Final Adjustments.—The engine is started by means of the priming valve and allowed to run until it is warm. The spark lever should be advanced throughout the whole of its travel. Gradually, the engine speed is then increased until it is equivalent to from 20 to 30 miles per hour in high gear. If necessary, the main needle *s*, Fig. 21 (*b*), is adjusted into a position that will give the engine its highest number of revolutions per minute without changing the setting of the throttle lever.

After the screw q_1 that clamps the needle regulating wire is loosened, the arrow on the dash regulator is set in a vertical position, and the main adjusting lever o_1 is moved into a position at right angles to the engine center line. The screw q_1 and the capscrew r_1 are now screwed down tight. This setting will permit quite extensive variations to be made between a rich and a lean mixture by means of the needle *s* and its dash control.

89. The car should then be driven in high gear on the road at a speed not slower than from 3 to 5 miles per hour, keeping the idling screw *o* closed as much as possible. If the speed is increased to 30 miles per hour and the adjustment is satisfactory with the dash regulator in the neutral position, the main-needle setting may be considered as being correct. If, at a speed of 50 miles per hour, the car operates better with the dash regulator moved toward either "Lean" or "Rich," the high-speed needle e_1, Fig. 21 (*c*), should be adjusted for a leaner or richer mixture, respectively. By screwing in the needle e_1 less gasoline is delivered; more, by screwing it out.

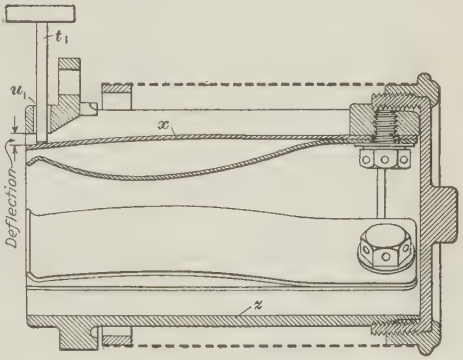

FIG. 22

With a correctly adjusted carbureter, it is possible to run the car through the entire range of speeds without having the carbureter either "load up" or show a "hollow spot," that is, fail at a certain stage to supply the required mixture. It is to be noted that if economical operation is desired, the dash regulator should be kept on the "Lean" side after the engine is warmed up.

90. When it is found necessary to inspect and check the auxiliary air valves, the case *z*, Fig. 21 (*b*), may be detached by removing the three screws s_1. Any dirt lodged between the reeds *x* and the case must be washed out, and the screen a_1 thoroughly cleaned.

The detached valve assembly is shown in longitudinal section in Fig. 22. If the reeds *x* are to be tested, the case *z* must be turned into such a position that the particular reed to be tested is on top, as at *x* in the illustration. Then the stem of a special weight t_1 is inserted in the hole u_1 and the deflection is noted. A different weight is used for each reed, the

weights to be applied for the various reeds being given in Table I, which also gives the required deflections, together with the dimensions of the reeds and other necessary data. Care should be taken to see that when the weight is removed from a reed, the latter will make full contact with the case and

TABLE I

DIMENSIONS OF REED VALVES, AND DATA RELATING TO TESTING OF REEDS

Reed Number	Grade	Thickness Inch	Reed Travel Inch	Weight Ounces	Deflection Inch
53138	Light	.012	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{16}$
53137	Intermediate	.018	$\frac{5}{32}$	$1\frac{1}{2}$	$\frac{1}{32}$
53136	Heavy	.018	$\frac{5}{32}$	2	$\frac{1}{32}$

not permit any air leakage. When the valve case is replaced on the carbureter, it is necessary that the light reed shall occupy a position corresponding to that of the reed *x*, Fig. 22. For this reason a letter T is stamped on the case flange, adjacent to the light reed.

GASOLINE AUTOMOBILE ENGINES
(PART 1)

PRINCIPLES AND ARRANGEMENT

FOUR-CYCLE PRINCIPLE

DEFINITIONS AND NAMES OF PARTS

1. An **internal-combustion engine** is an engine in which power is generated by burning within the cylinder a combustible mixture of air and gasoline, air and kerosene, or air and any other liquid fuel. The burning of the fuel results in the production of gases of high temperature and pressure, which act directly on a piston that moves back and forth in a cylinder to which the air and fuel are admitted and from which the burned gases are discharged by suitable means. The required mechanical work is done by the piston through the proper mechanism. Internal-combustion engines are classified as *single-acting* and *double-acting engines,* depending on their construction and operation. Engines in which the cylinder is so constructed that gas is admitted to only one end and burned on only one side of the piston are *single-acting engines,* because the expanding gases force the piston in but one direction; engines in which gases are admitted to each end of the cylinder alternately, and burned first on one side of the piston and then on the other, forcing it first in one direction and then in the other, are *double-acting engines.* All gasoline automobiles now in use are driven by some type of the single-acting internal-combustion engine. Double-acting internal-

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combustion engines have never proved successful as automobile engines, but are used to some extent as stationary engines, being sometimes employed in power plants where gas instead of gasoline is used as fuel.

2. In Fig. 1 is presented an external view of the right side, and in Fig. 2 a view of the left side, of a typical four-cylinder poppet-valve gasoline engine as used in the different models of the Dodge Brothers automobile. The same parts, as far as possible, have been lettered the same in both illustrations, and both should be referred to in reading the description.

The cylinders are cast in a single block *a*, the upper end of which is fitted with a detachable cylinder head *b*. The cylinder block is cast in one piece with the upper half *c* of the crank-case, the lower half *d* of which is detachable in order to give access to some of the interior parts of the engine. The upper crank-case supports a shaft with four cranks, called the crank-shaft, which extends the entire length of the crank-case; this shaft cannot be seen in either illustration, because it is enclosed in the crank-case. The crank-shaft, being rapidly rotated by the up-and-down movement of the pistons in the cylinders, through suitable cranks and connecting-rods, imparts a rotary motion to the driving mechanism of the automobile through a clutch located at the rear of the engine and inside of the casing *e*.

The combustible mixture enters the middle of the cylinder block through an opening shown covered by the carbureter flange *f*, Fig. 2. In this particular engine there is no separate manifold, the openings to the different cylinders being cast inside of the block *a*. The burned gases, resulting from the explosions, pass through the exhaust manifold *g*, Fig. 1, there being a separate connection from the manifold to each cylinder block. The exhaust manifold is connected at one end to a muffler, which is not shown; the muffler is a device that suppresses the loud noise of the exhaust. The piping *h* and water pump *i* are for the purpose of circulating water through jacket spaces surrounding the cylinders and thus cooling them and pre-

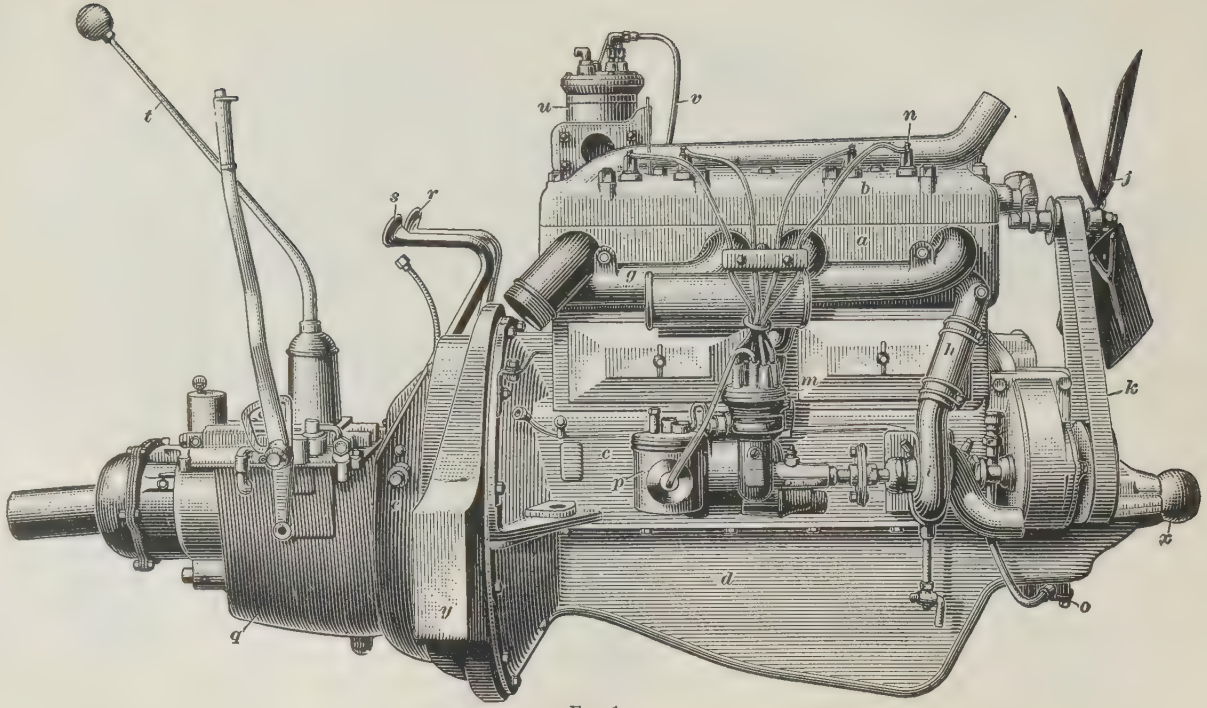


FIG. 1

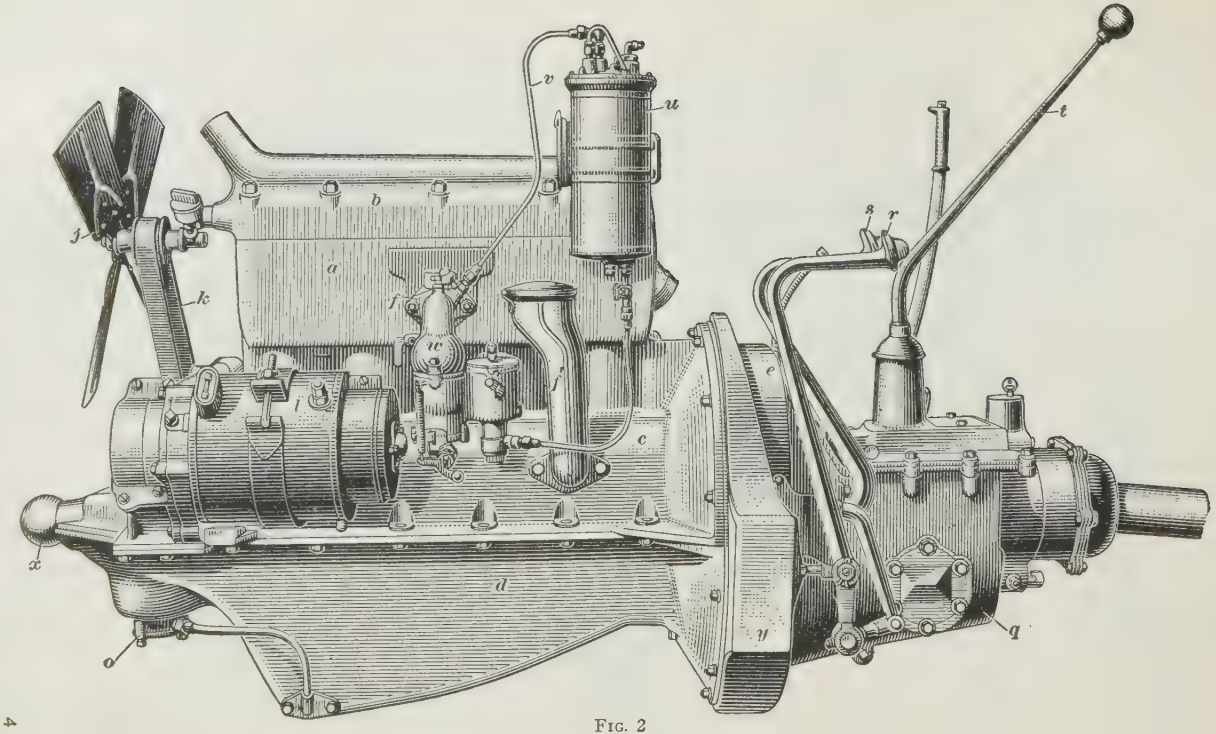


FIG. 2

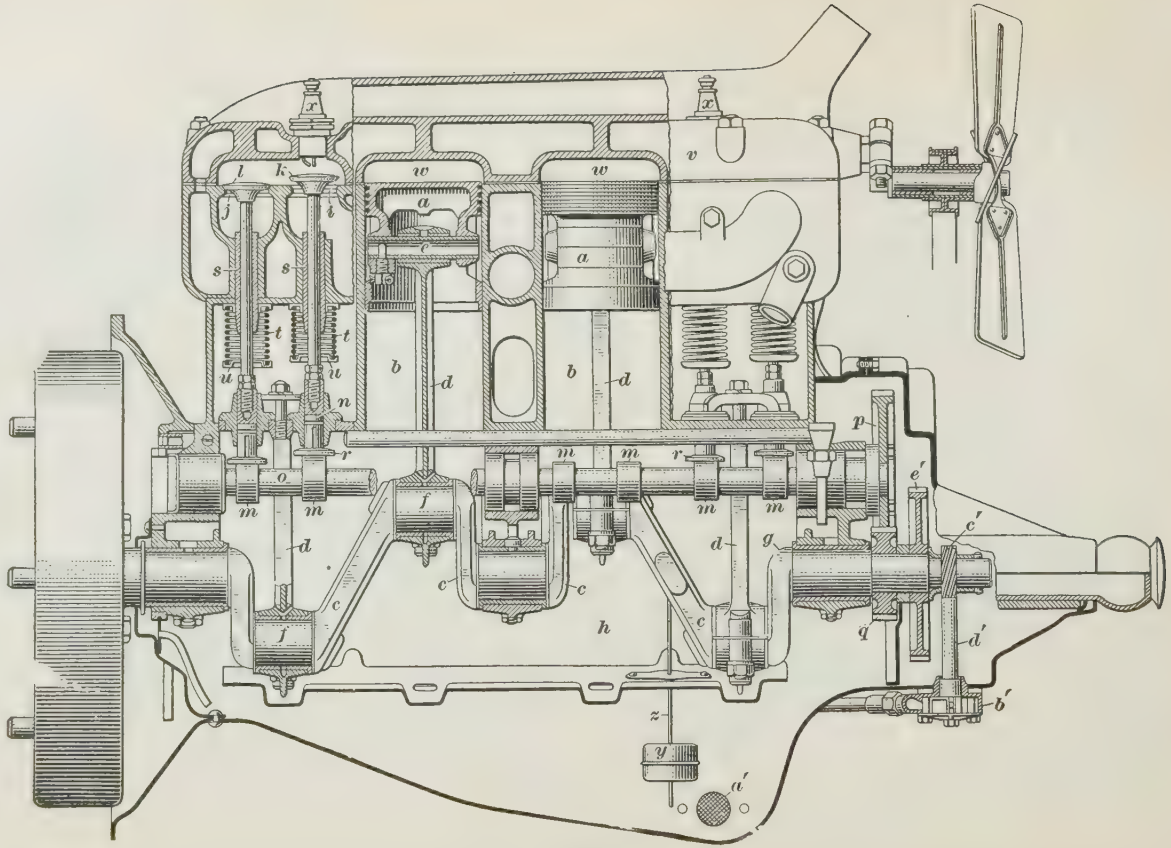
venting them from being injured by the heat due to the explosions. The fan *j*, located at the forward end of the engine and driven by the belt *k*, also belongs to the cooling system, its purpose being to draw air through a radiator, which is used to cool the circulating water. Other important parts shown are the electric motor-generator *l*, Fig. 2, which is used to start the engine, and to supply current for lighting purposes and ignition, and charging a storage battery carried in the car; the timer-distributor *m*, Fig. 1, for distributing a high-tension electric current to the spark plugs *n*; the oil pump *o*, which forces the lubricating oil through the oiling system, and the ignition coil *p* which, working in conjunction with a source of low-tension electric current and the timer-distributor, changes the low-tension current to a high-tension current. The transmission, or change-speed gear, is inside the casing *q*; the clutch pedal *r* operates the clutch, and the brake pedal *s* the foot brakes on the rear wheels. The gear-shift lever is shown at *t*.

A vacuum tank *u* supplies gasoline through the gas pipe *v* to the carbureter *w*, Fig. 2, where the gasoline is vaporized and mixed with the correct proportion of air to form a combustible mixture. The front engine support is shown at *x* and one of the rear supports is shown at *y* in each view.

The crank-shaft of the engine, as is now universal practice with gasoline automobile engines, revolves in a clockwise direction when viewed from the front end of the car, which means that it revolves counter-clockwise when viewed from the driver's seat.

3. A part sectional side view of the engine shown in Figs. 1 and 2, is shown in Fig. 3, the cylinder block and crankcase being cut away so as to reveal the arrangement of the parts inside of the engine. The outer attachments of the engine are omitted in order to simplify the view.

The pistons *a* are free to move up and down within the hollow, or bore, of the vertical cylinders *b*. The pistons are connected to the cranks *c* by means of the connecting-rods *d*, which are attached at their upper end to the piston pins *e* and at the lower end to the crankpins *f*, so that an up-and-down


x
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f
d
d
g
c
c
c
c
h
j
p
e′
c′
q
d′
b′
z
y
a′

Fig. 3

motion of the pistons causes the cranks to rotate. The crank-shaft *g*, being integral with the cranks, also rotates, and through it the driving mechanism of the car is caused to turn. The crank-shaft is carried in bearings supported by the crank-case *h*.

At *i* is seen an opening called the inlet port, through which the mixture of gasoline vapor and air enters the cylinders; and at *j* is the exhaust port, through which the burned gases, or products of combustion, are expelled. These openings are fitted with valves *k* and *l*, called the inlet valve and the exhaust valve, respectively, by means of which the ports may be closed. The wall of the port on which the valve rests when in the closed position is known as the valve seat. The valves are operated by means of cams *m* and valve lifters *n*. The cams are carried on a cam-shaft *o*, which is rotated by means of gears *p* and *q* from the crank-shaft *g*, and, as the cams revolve, the lobes, or raised portions, strike on and raise the valve lifters, which in turn lift the valves. The cam-shaft always rotates at one-half the speed of the crank-shaft; in other words, for every two revolutions of the crank-shaft the cam-shaft makes one revolution. It will be noticed that in the illustration the inlet-valve cam is turned so that its lobe is directly underneath the valve lifter, in which position the inlet valve is raised and the inlet port opened; the lobe of the exhaust valve cam is at one side of the valve lifter, in which position the exhaust valve remains on its seat in a closed position. The valve lifters are provided at the bottom with valve followers *r* on which the cams strike. The valves are held in place by the valve-stem guides *s* in which the valve stems slide and by the valve springs *t*. The springs are constantly compressed so that they push downwards on the valve-spring retainers *u* and keep the valves closed except when the lobes of the cams strike the valve lifters.

The cylinder head is seen at *v* and between it and the valves is the space *w*, called the combustion chamber, or the compression space, because it is in this space that the burning, or combustion, of the fuel, takes place. In the cylinder head are the spark plugs *x*, which are screwed into the combustion chamber for the purpose of producing, in conjunction with the other parts of the ignition system, electric sparks to ignite the fuel.

The hollow float *y* is placed in the oil reservoir of the crank-case so as to indicate by means of a rod *z*, the quantity of oil in the reservoir at any time, and the screen *a'* strains the oil before it passes into the pump *b'*. The pump *b'* is driven from the crank-shaft by helical gears, one of which is shown at *c'*, and the shaft *d'*. The starter generator shown at *l*, Fig. 2, is driven by a silent chain from the gear *e'*, Fig. 3. The breather pipe, or oil filler, through which oil is poured into the crank-case *d*, Fig. 2, is shown at *f'*.

4. The end of the cylinder that is attached to the crank-case is called the crank-end, and the other end is called the head end. The movement of the piston from the head end to the crank-end is called the forward, or outward, stroke; the movement in the opposite direction is called the return, or inward, stroke.

When the piston has reached the end of either stroke, the connecting-rod and crank are in a straight line, and the pressure of the gases on the piston is transmitted directly to the crank and bearings, none of it being used to turn the crank. When the crank occupies this position it is said to be on its *dead center*. There are two dead-center positions, corresponding to the two extreme positions of the piston. When the piston is at the extreme bottom end of its stroke, the crank is on its outer, or lower, dead center; and when the piston is at the extreme top end of its stroke, the crank is on its inner, or upper, dead center.

5. The *charge* is a mixture of fuel and air taken in at one stroke of the engine. It varies according to the condition of operation, and may sometimes be sufficient to fill the cylinder completely at atmospheric pressure, while at other times it may be reduced. The proportions of fuel and air may also vary from time to time.

The burned gases, which are expelled from the engine after having performed the work required, are known as the *exhaust gases*, or, simply, the *exhaust*. These gases are waste products and are allowed to escape into the atmosphere.

6. Gasoline automobile engines are either *vertical, horizontal,* or of the **V** type, depending on the manner in which the cylinders are arranged. Engines having their cylinders arranged vertically as in Figs. 1, 2, and 3, are in most common use; the other engines in current use are of the **V** type, the cylinders of such engines being arranged in the shape of a **V**. Horizontal engines were at one time used occasionally in automobiles, and are now used a very little in motor trucks.

GASOLINE-ENGINE CYCLE

7. A *cycle* is a chain, or series, of events, or happenings, occurring over and over in the same order. Thus, the four seasons of the year, or the movement of the hands of a clock around the dial, may be said to constitute a cycle, because they are constantly recurring, and always in the same order. As applied to a gasoline engine, the term cycle refers to the operations, or events, that take place within the cylinder from one explosion to the next, and by means of which the fresh charge is drawn into the combustion chamber and exploded and the exhaust gases expelled. These events always occur in the same order and are repeated after each explosion. The cycle on which an internal-combustion engine operates is one of the distinguishing features of different types.

8. The modern cycle of gasoline engines is known as the Beau de Rochas cycle, after the name of the inventor, and more commonly as the Otto cycle, after the name of the engineer who carried out its early commercial application. This cycle, in its broad and strictly scientific meaning, does not take into consideration the method of getting the charge of combustible mixture into the cylinder or that of expelling the hot burned gases.

The steps of the cycle in an engine are as follows: Suppose that, at the beginning of operations, the valves are closed, that the piston is at its position farthest out toward the crankshaft, and that the cylinder is filled with a combustible mixture at atmospheric pressure. By forcing the piston inwards to the

completion of the inward stroke, the charge will be compressed into the compression space, or combustion space. Now by igniting the compressed charge, the pressure will be increased still more by the heat of combustion. The pressure tends to drive the piston outwards, and as soon as the rotating crank-shaft has made the angle between the connecting-rod and the crank sufficiently great, the pressure of the hot gases against the piston face will drive the crank-shaft around. The burned gases expand to fill the increasing volume of the cylinder as the piston moves outwards, and the pressure decreases. At the completion of the outward stroke, the exhaust valve is opened and the hot burned gases escape by expansion until the pressure falls to that of the atmosphere. This completes the Otto heat cycle.

9. The method of expelling the burned gases that remain in the cylinder at atmospheric pressure and of taking in a fresh charge of combustible mixture has not yet been considered. This is accomplished in two distinct ways, which form the foundation for the commercial names *four cycle* and *two cycle,* as applied to automobile engines.

10. A *four-cycle,* or, more correctly, a *four-stroke cycle, engine* is one in which four complete strokes of the piston are required to complete the cycle. In this engine the burned gases remaining in the cylinder after the exhaust valve has been opened and part of the hot gases removed by expansion, are expelled in part by a separate inward stroke of the piston, and a fresh charge is drawn into the cylinders through the inlet port by a separate outward stroke. Generally speaking, one event occurs during each of the four strokes of this cycle; that is, if the stroke by which the charge is drawn into the cylinder is considered the first stroke, the mixture is compressed during the second stroke, burned during the third stroke, and the exhaust gases are expelled during the fourth stroke, after which the conditions are the same as at first and the cycle is complete.

11. A *two-cycle,* or, more correctly, a *two-stroke cycle, engine* is one in which only two strokes of the piston, corre-

sponding to one revolution of the crank-shaft, are required to complete the cycle. In this cycle an explosion occurs on each downward stroke of the piston, the fresh charge being admitted and the exhaust gases expelled at or near the end of this stroke. Hence, for the same number of revolutions of the crank-shaft, there are twice as many explosions in the cylinder of a two-cycle engine as in that of a four-cycle engine. However, this does not mean that the power developed by a two-cycle engine is twice as great as that produced by a four-cycle engine of the same size and speed, for, on account of the inefficient *scavenging*, or cleaning, of the cylinder after the explosion and the lower compression pressure in the two-cycle engine, the explosions are not so powerful as in the four-cycle engine. It is generally estimated that a two-cycle engine of a certain size and speed will develop about 1.65 times as much power as a four-cycle engine of the same size and speed.

While two-cycle engines are common in marine and stationary work, they are not used any more in passenger cars or motor trucks, and therefore will not be described.

12. The two types of internal combustion engines just defined are sometimes designated by the longer terms *four-stroke Otto-cycle engine* and *two-stroke Otto-cycle engine* to distinguish them from other engines that operate on cycles that differ from the Otto. However, since all automobile engines of the internal-combustion class operate on the Otto cycle, the terms four-cycle and two-cycle are sufficiently definite in meaning when limited to this field of application.

13. It has been found that by compressing the charge before igniting it, a greater amount of power can be obtained from a given quantity of fuel than by simply burning it at atmospheric pressure. In other words, the efficiency of the internal-combustion engine is increased by compressing the charge before igniting it. Compressing the charge heats it; hence, on account of the danger of overheating the cylinder the compression pressure is generally limited to from 60 to 75 pounds per square inch, as shown by a pressure gauge. Another disadvantage of too high a compression is that the bearings

and joints of the moving parts of the engine are liable to give trouble by knocking or pounding. All internal-combustion automobile engines compress the charge before igniting it.

OPERATION OF FOUR-CYCLE ENGINE

14. As already explained, four separate strokes of the piston, two outwards and two inwards, are required to complete a cycle in the cylinder of a four-stroke cycle engine. In this connection, the engine follows closely the operation of the old-style muzzle-loading cannon, and the latter forms an excellent illustration of the events that are required to complete the cycle in the engine. The various steps in the loading and firing of the muzzle-loading cannon are as follows: First, a charge of powder is inserted into the mouth of the cannon, and pushed to the inner end of the bore by a ramrod; the charge is next compressed solidly in place by packing wadding against it with the ramrod, and the ball is inserted; the next step is to fire the compressed charge, and drive the ball out of the bore; the final step is to shove the ramrod into the bore once more to drive out the smoke, or gases, remaining in the cannon. The gun is then ready for reloading.

Now follow the action of the four-cycle internal-combustion engine, and note how closely it resembles the operation of the cannon as just described. The four strokes that make up the cycle of the engine are, in order, the suction stroke, the compression stroke, the firing stroke, and the exhaust stroke. During the first, or suction, stroke of the engine, the fresh gas is taken into the cylinder, in which respect it corresponds to the loading of the cannon. On the second, or compression, stroke, the gas is compressed into a small space at the top of the cylinder, thereby resembling the packing or compressing of the charge in the cannon. The third stroke is the firing stroke during which the compressed charge is fired, and the burning gas drives the movable piston outwards. Here again the analogy is closely carried out, as, in the corresponding event in the cannon, the compressed charge is fired, and the movable ball is driven out of the muzzle. During the fourth and final

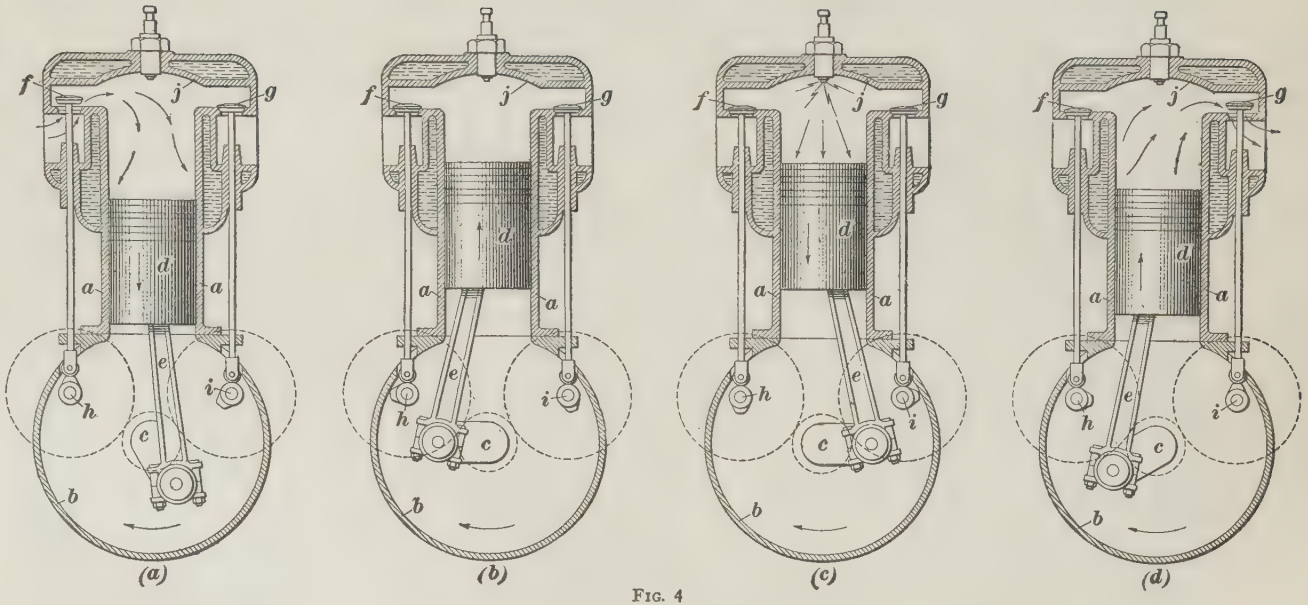

FIG. 4

stroke of the engine cycle, the piston moves inwards once more and drives the burned gases from the cylinder, thereby resembling the swabbing or cleaning out of the cannon.

The four strokes of the cycle are shown diagrammatically in Fig. 4, which presents four cross-sectional views, each showing the cylinder *a* and crank-case *b* cut at right angles to the crank-shaft *c*, exposing to view the piston *d*, connecting-rod *e*, inlet and exhaust valves *f* and *g*, and cams *h* and *i*. These views illustrate the various steps in the operation of the four-cycle type of automobile engine and the corresponding positions of the valves. The engine presented in the illustration does not represent any particular make but shows the principle on which all four-cycle gasoline engines are operated. If the different events here described are understood there will be no difficulty in comprehending the operation of any engine of this type.

15. The first stroke in the operation of the engine is shown in Fig. 4 (*a*). During this stroke the piston *d*, following the motion of the crank-shaft *c*, which is being propelled by the force of the preceding explosion, or by the starter, either hand or electrical, if the engine is just being started, moves downwards as indicated by the straight arrow. At or slightly after the time that the piston starts on this stroke, the inlet valve *f* is opened by means of the cam *h*. The downward motion of the piston tends to produce a vacuum in the upper part of the cylinder, so that combustible mixture flows into the cylinder through the inlet port, as shown by the curved arrows, to fill up this vacuum, or, in other words, a charge is drawn into the cylinder. At the end of this stroke, or slightly after, the inlet valve closes. The exhaust valve *g* is kept closed during this stroke so that none of the exhaust gases can enter through the exhaust port. Because of the fact that the combustible mixture is drawn into the cylinder during this stroke, it is usually called the *suction stroke*, although it is also variously known as the *charging stroke, admission stroke, inlet stroke,* and *induction stroke.*

16. During the second stroke in the cycle of operations the piston *d*, still driven by the crank-shaft *c*, moves upwards

as shown by the arrow in Fig. 4 (*b*). Both the inlet valve *f* and exhaust valve *g* are closed during this stroke, so that the combustible mixture that was drawn into the cylinder on the suction stroke is now compressed into the small space between the top of the piston, when it is at the top of its stroke, and the cylinder head *j*. By thus compressing the charge into a small space before igniting it, a greater amount of power can be obtained from a given quantity of fuel, as previously explained. About the time that this stroke, which is called the *compression stroke,* is completed, the charge is ignited by means of an electric spark.

17. The combustible mixture that was drawn into the cylinder on the first stroke of the piston and compressed on the second stroke is completely burned during the third stroke, when the piston is again on its downward movement, as shown in Fig. 4 (*c*). The combustion of the charge is so rapid during this stroke as to be practically instantaneous, and is usually called the *explosion.* The pressure in the cylinder, resulting from the explosion, drives the piston downwards and outwards, turning the crank-shaft by means of the connecting-rod and crank. Both valves remain closed from the beginning to nearly the end of this stroke. The exhaust valve *g* is opened by the cam *i* just before the end of the stroke and part of the burned gases escape into the air, so that the pressure in the cylinder falls nearly as low as that of the atmosphere. It is during this downward stroke of the piston that work is done and a forward impulse is given to the piston, so that it is called the *working stroke, impulse stroke, explosion stroke,* or *combustion stroke.*

18. In Fig. 4 (*d*) the piston *d* is seen on the fourth and last stroke of the cycle. During this stroke it moves upwards, being driven by the crank-shaft, and expels the greater part of the remaining burned gases from the cylinder through the exhaust port. However, the combustion chamber, between the cylinder head and the face of the piston when at the top of its stroke, remains filled with the burned gases at the completion of this stroke. The pressure of these residual gases is generally about the same as, or somewhat higher than, that of

the external atmosphere. The inlet valve remains closed during this stroke and the exhaust valve remains open, it being closed about the time that the piston reaches the end of its stroke. This upward movement of the piston is known as the *exhaust stroke,* and its completion ends the cycle of operations. Following the exhaust stroke, the suction stroke again begins and the series of operations takes place over and over in exactly the same order.

19. Four-cycle automobile engines are classified as *poppet-valve engines* and *non-poppet-valve engines,* depending on the type of valve used for controlling the admission of fuel into the cylinder and the escape of burned gases therefrom.

Poppet-valve engines are those that make use of the so-called poppet type of valve, such as shown in Figs. 3 and 4; *non-poppet-valve engines* are those that employ other types of valves for inlet and exhaust, such as sliding valves or rotary valves. Non-poppet-valve engines operate on exactly the same principle as the poppet-valve engine just described.

TYPICAL VERTICAL AUTOMOBILE ENGINES

GENERAL CONSTRUCTION

20. The typical automobile engine has from four to eight cylinders, is of the four-cycle type, and runs on an average about 2,000 revolutions per minute at full speed. As a general thing, the maximum speed is about 3,000 revolutions per minute, although several engines are being built that exceed this limit. Automobile engines develop in general from 20 to 80 horsepower, depending on the size and number of cylinders. The speed and power of the engine are ordinarily governed by regulating the amount and quality of the charge that enters the cylinders, and by varying the time at which the mixture is fired. This is accomplished by the levers that are usually located on or near the steering wheel in front of the driver, although in many engines the time of ignition is also varied by

an automatic device, or governor. Some motor-truck engines are also provided with an automatic governor by means of which the fuel supply is automatically regulated, so that the truck cannot exceed the speed for which the governor is set.

21. In a number of the earlier makes of automobiles, engines with a single cylinder or with two cylinders were used as a means of propulsion, but as the automobile industry developed, engines with a greater number of cylinders were required in order to secure the power and smooth running demanded in the modern passenger car. As a result, the four- to eight-cylinder four-cycle engines are used on practically all passenger cars of today, and the single- and double-cylinder types are not being manufactured for this purpose, although a few of these engines are still in existence. A few motor trucks still use two-cylinder engines, however. Twelve-cylinder engines have been used to a certain extent in automobiles, but none are being manufactured for this purpose at present. They are proving very successful, however, in air-craft work.

ARRANGEMENT OF ENGINE CYLINDERS

22. Four-Cylinder Arrangement.—The four-cylinder four-cycle gasoline engine, which is a widely used type of automobile engine, has its cylinders vertically arranged on one side of the crank-shaft. This arrangement is seen in Fig. 5, which is a diagrammatic illustration showing the cylinders cut in half and exposing to view the pistons *a*, the cranks *b*, and the connecting-rods *c*.

For each cylinder of a four-cylinder engine there is a corresponding crank; hence, in this engine there are four cranks, each one being part of the crank-shaft *d*, which is offset to form the cranks as shown. In order to secure a uniform application of power and smooth running of the engine, it is essential that the cranks be arranged around the crank-shaft in such a manner that no two pistons will be on their impulse strokes at the same time, but that the explosions in the various cylinders will occur in regular order with equal intervals of time between

them. This result is obtained by placing the cranks so that the two end ones are on one side of the crank-shaft and directly opposite the two middle ones, which are on the other side of the crank-shaft. In other words, the cranks of a four-cylinder

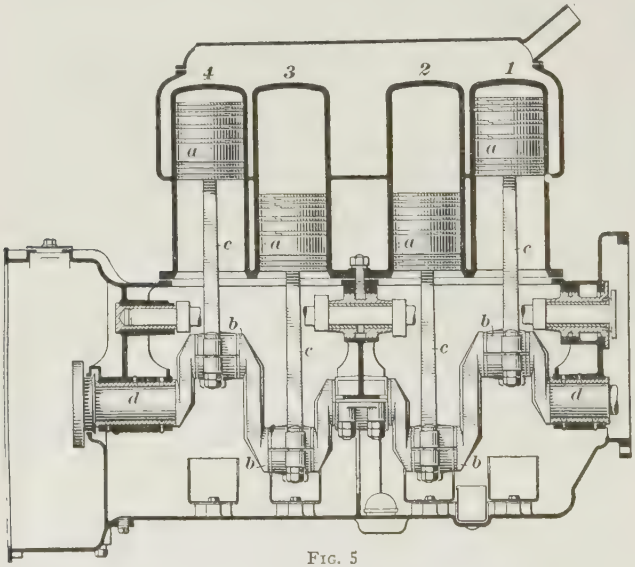

FIG. 5

four-cycle engine are arranged so that when the two end ones stand vertically upwards, the two middle ones stand vertically downwards, as shown in Fig. 5. The two outer cranks are then said to be at an angle of 180° with the two inner ones.

23. Order of Explosions of Four-Cylinder Engines. With the cranks of a four-cylinder four-cycle engine arranged as shown in Fig. 5, two of the pistons will be descending while two are ascending. For instance, while the pistons in cylinders *1* and *4* are descending on their working and suction strokes, respectively, those in cylinders *2* and *3* are moving upwards on their compression and exhaust strokes. During the half of a revolution of the crank-shaft represented by these movements of the pistons, the explosion occurs in cylinder *1* and work is done in that cylinder. At the same time a charge is being compressed in cylinder *2*, so that during the following

half revolution, the piston in cylinder *2* is on its working stroke, that in cylinder *3* is on its suction stroke, and those in cylinders *1* and *4* are moving upwards on their exhaust and compression strokes, respectively. During the third half revolution, the pistons in cylinders *1* and *4* again descend; this time, however, with that in cylinder *4* on its working stroke and that in cylinder *1* on its suction stroke, the pistons in cylinders *2* and *3* are at the same time ascending on their exhaust and compression strokes, respectively. On the fourth half revolution of the crank-shaft, when the pistons in cylinders *2* and *3* descend, that in *3* is on its working stroke, and that in *2* is on its suction stroke, while those in cylinders *1* and *4* move upwards on their compression and exhaust strokes, respectively. On the following strokes of the pistons an explosion will again occur in cylinder *1*, and the same order of events as just named is repeated as the crank-shaft revolves.

In brief, the order in which the explosions, or impulses, take place in the various cylinders of a four-cylinder four-cycle automobile engine is as follows: In the first case, starting with cylinder *1*, an explosion first occurs in that cylinder, then one occurs in cylinder *2*, then in cylinder *4*, and finally in cylinder *3*. Two full revolutions of the crank-shaft are necessary in order to complete the various operations required to produce an explosion in each cylinder; hence, an impulse is given to the crank-shaft each half of a revolution. The order in which the impulses occur in the various cylinders is called the *order of explosions* or the *order of firing*. The order of firing just explained is said to be one, two, four, three, or, more briefly, *1–2–4–3*.

Since the pistons in cylinders *1* and *4* move together, or in unison, and those in cylinders *2* and *3* also move together, or in unison, in a four-cylinder four-cycle engine, it is evident that the events taking place in cylinders *1* and *4* may be reversed, or those taking place in *2* and *3* may be reversed, in which case the order of firing becomes one, three, four, two, or *1–3–4–2*. The sequence of events may be traced out in the manner explained by substituting cylinder *4* for cylinder *1*, or cylinder *2* for cylinder *3*, and vice versa.

The two orders of firing just named are used exclusively in four-cylinder four-cycle automobile engines. The order employed depends on the manner in which the valve cams are set to open and close the inlet and exhaust valves; naturally, the sequence in which the ignition spark is made to occur in the several cylinders must be the same as called for by the construction of the engine.

With vertical engines it is the usual practice to assign the number 1 to the cylinder nearest the front end of the car and to number those to the rear of it in succession 2, 3, etc.; with V-type engines there is no standard practice of numbering the cylinders, however.

It is impossible to change the firing order of an engine without changing the cam-shaft; manufacturers are not usually prepared to furnish cam-shafts for a different firing order, as nothing is gained by the change.

24. Six-Cylinder Arrangement.—On account of their flexibility and smooth running qualities, automobile engines having six cylinders are used very extensively at the present time. The six-cylinder engines are much the same in form as the usual type of four-cylinder engines, the cylinders being arranged vertically in a row above the crank-shaft.

The cranks in a six-cylinder engine are arranged in pairs; that is, there are three pairs, each pair consisting of two cranks located on the same side of the crank-shaft and in the same plane. The two cranks of a pair may be either adjacent to each other or separated by other cranks placed between them. A common arrangement is shown in Fig. 6, which is a diagrammatic illustration showing the relative positions of the cranks and pistons. The cranks *a* and *f* form a pair, *b* and *e* form a pair, and *c* and *d* form a pair, the cranks of each pair being in line, as shown in the view on the right. As generally stated, the cranks of cylinders *1* and *6* form a pair, those of cylinders *2* and *5* form a pair, and those of cylinders *3* and *4* form a pair. The pairs are located at equal intervals around the crank-shaft, that is, at an angle of 120 degrees with each other; in some cases, cranks *2–5* and *3–4* being located as shown at *b-e*, and

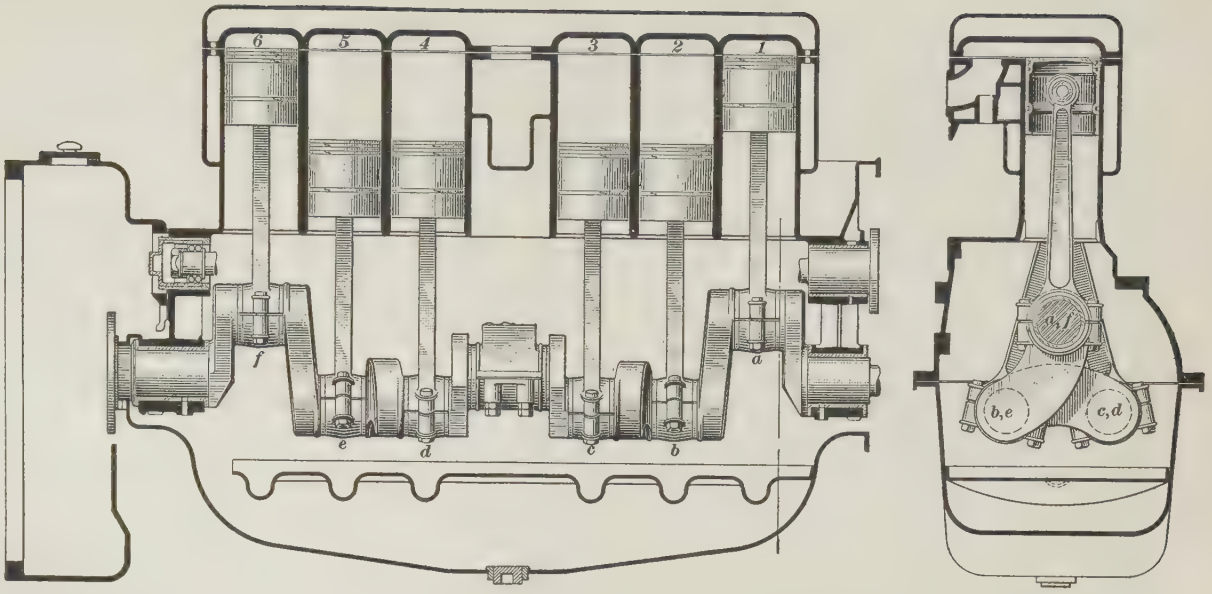

FIG. 6

c-d, respectively, and in other cases, these two pairs are reversed, being located on opposite sides of the crank-shaft from those shown. The two pistons of each pair move in unison, that is, when one piston is on its up stroke, the other is also on its up stroke, and when one is on its down stroke, the other is also on its down stroke.

25. Order of Explosions of Six-Cylinder Engines.—The impulses in the cylinders of a six-cylinder four-cycle automobile engine occur at intervals of one-third of a revolution; therefore, there are three impulses per revolution. Considering the cylinders as being in pairs, corresponding to the three pairs of cranks, the explosions first occur in one cylinder of each pair and then in the other cylinder of each pair in the same order.

There are eight possible firing orders with a six-cylinder engine but of these eight possible orders, only two are used in practice, which are *1–5–3–6–2–4*, with the cranks located as shown in Fig. 6, and *1–4–2–6–3–5*, with cranks *2–5* and *3–4* on opposite sides of the crank-shaft from those shown, experience having taught that there is less interference of the exhaust from each cylinder with that of the others than with the other possible firing orders, excepting *1–3–2–6–4–5*; this last-named firing order has not come into extensive use, however.

In practice, the different firing orders are obtained by using different arrangements of the cams that open the inlet and exhaust valves, and employing ignition systems wired so that the electric spark is sent to the cylinders in the sequence desired.

26. Eight-Cylinder Arrangement.—A properly designed eight-cylinder four-cycle engine will give four impulses to the crank-shaft during each revolution, a six-cylinder engine will give three impulses, and a four-cylinder engine only two impulses. Consequently, an eight-cylinder engine as used in automobile practice, exerts a very uniform turning effort on the crank-shaft, which results in a smooth running of the engine.

There are two types of eight-cylinder engines used on automobiles; in one case, the cylinders being arranged in blocks of four, each set at an angle to the other, and in the other, the cylinders are arranged in a straight line. The first type of

engine is known as the **V** type, whereas the second is known variously as the vertical-8, 8-in-line, single-8, or straight-8 engine. **V**-type eight-cylinder engines are usually built with the two blocks set at right angles to each other, and the cranks are arranged as in the case of a simple four-cylinder engine. In other words, the **V**-type eight-cylinder engine generally consists in the main of two four-cylinder engines operating on the same crank-shaft, the impulses alternating so as to occur every 90 degrees of crank-shaft rotation, rather than 180 degrees as in the simple four-cylinder engine. Exceptions to the foregoing general arrangement are found in the late model Cadillac, in which the cranks are arranged in two planes 90 degrees apart, the engine thus really forming four two-cylinder engines, and in the Lincoln and Wills Sainte Claire cars, in which the engine cylinders are set 60 degrees apart, instead of the conventional 90 degrees, the impulses occurring alternately 60 degrees and 120 degrees apart.

27. Firing Order and Sequence of Events in Eight-Cylinder V-Type Engines.—In considering the firing orders of eight-cylinder **V**-type engines having the cranks arranged as in a four-cylinder engine, it is well to keep in mind that each group of four cylinders can have only the same two firing orders that any four-cylinder engine can have in order that the explosions may occur 180 degrees apart for the cylinders of the same block. These firing orders are *1–2–4–3* and *1–3–4–2*, the cylinders being numbered from the radiator end of the engine toward the rear. In order to make clear the firing orders of the eight-cylinder **V**-type engine, Fig. 7 is presented. This illustration shows in diagrammatic perspective, an eight-cylinder **V**-type engine with the cranks in pairs 180 degrees apart. The engine is shown as viewed from the front, and as the right and left sides of an engine are always designated as viewed from the driver's seat, the right group of cylinders is shown at the left, and the left group at the right of the illustration. With the crank-shaft turning clockwise, as shown by the arrow, or counter-clockwise if viewed from the driver's seat, there are eight possible firing orders of the engine. These

possible orders, however, are reduced to two when a single camshaft with eight cams is employed to operate all of the valves of the engine, as is the usual construction. These orders are:

1 right–*4* left–*2* right–*3* left–*4* right–*1* left–*3* right–*2* left (1)

1 right–*4* left–*3* right–*2* left–*4* right–*1* left–*2* right–*3* left (2)

The favorite firing order is that given at (2). This firing order, and also that given under (1), can be easily brought to

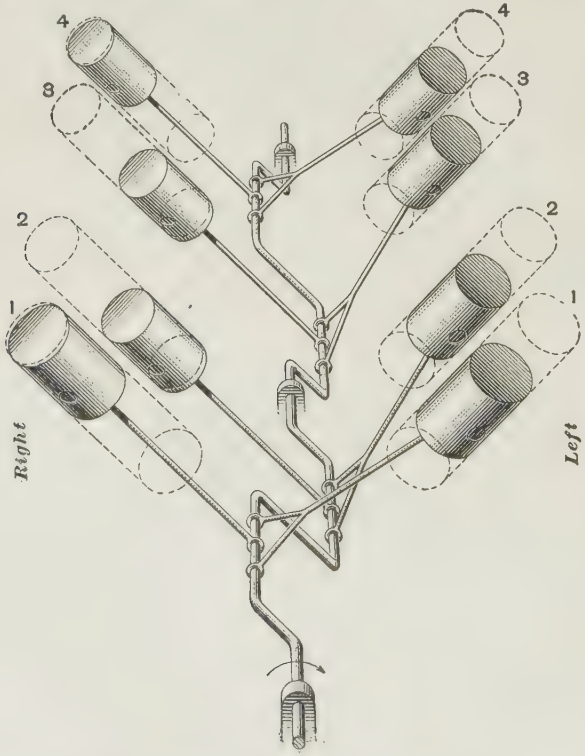

FIG. 7

the mind by remembering that the sum of the numbers of each pair of cylinders which fire in succession is 5. Thus, taking firing order (2), *1* right–*4* left = 5; *3* right–*2* left = 5; *4* right–*1* left = 5; *2* right–*3* left = 5.

28. It is the practice of some builders of eight-cylinder V-type engines to number the cylinders from *1* to *4* on the right

side of the car, beginning at the front, and from *5* to *8* on the left side of the car, beginning at the front. With this manner of numbering the cylinders the firing order given under (*2*) becomes *1–8–3–6–4–5–2–7*. Some engines, for instance, those used in the eight-cylinder Cadillac car, have marked on their cylinders the sequence in which they fire. Thus, the firing

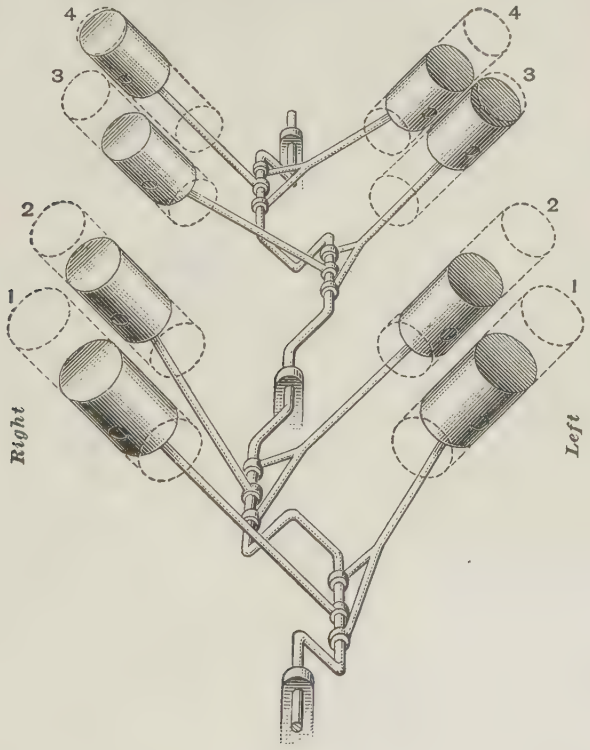

Fig. 8

order given under (*2*) in Art. **27** is used in the earlier models of the Cadillac engine, and the cylinders are marked as follows: *1* left is marked *1*; *2* right is marked *2*; *3* left is marked *3*; *1* right is marked *4*; *4* left is marked *5*; *3* right is marked *6*; *2* left is marked *7*; *4* right is marked *8*.

By referring again to Fig. *7*, it will be noted that the cranks are in their dead-center position for the right group

of cylinders, and that consequently all pistons of the left group are near their mid-position. With the firing order (2), Art. **27**, the events occurring in each cylinder with this crank position are as follows, assuming that ignition has just occurred in cylinder *1* on the right: In cylinder *1* on right, the explosion stroke is beginning; in cylinder *2* on right, the piston is making the exhaust stroke; in cylinder *3* on right, the piston is on its compression stroke; in cylinder *4* on right, the suction stroke is beginning; the piston of cylinder *1* on left is on its exhaust stroke; the piston of cylinder *2* on left is on its suction stroke; the piston of cylinder *3* on left is on its explosion stroke, and the piston of cylinder *4* on left is on its compression stroke.

29. The arrangement of the cranks of the later models of the Cadillac engines is shown in diagrammatic perspective in Fig. 8. The cranks of cylinders *1* and *2* are 90 degrees apart; those of cylinders *2* and *3* are 180 degrees apart; and those of cylinders *3* and *4* are 90 degrees apart. With this arrangement of the cranks, the firing order is *1* left–*4* right–*4* left–*2* left –*3* right–*3* left–*2* right–*1* right. By referring to the diagram, it will be seen that the piston in cylinder *1* left is ending its downward stroke; piston *1* right is beginning its upward stroke; piston *2* left is starting its upward stroke; piston *2* right is ending its upward stroke; piston *3* left is beginning its downward stroke; piston *3* right is ending its downward stroke; piston *4* left is ending its upward stroke; and piston *4* right is beginning its downward stroke. With the firing order as just described, it being assumed that the ignition has just occurred in the cylinder *4* right, the events occur in each cylinder as follows: In cylinder *4* right, the working stroke is just started; in cylinder *1* left, the working stroke is ending; in cylinder *1* right, the exhaust stroke is started; in cylinder *2* left, the compression stroke is begun; in cylinder *2* right, the exhaust stroke is ending; in cylinder *3* left, the suction stroke is beginning; in cylinder *3* right, the suction stroke is ending; and in cylinder *4* left, the compression stroke is ending. The engine rotates clockwise during these events, when viewed from the front.

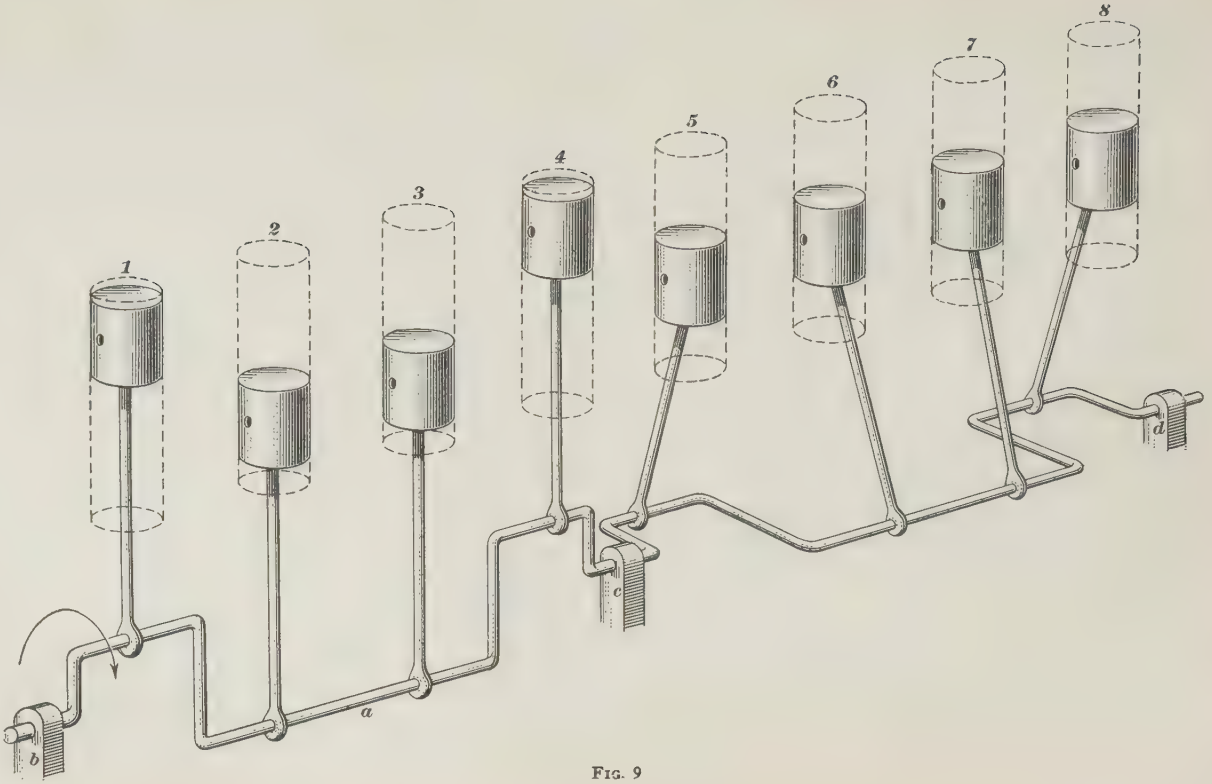

FIG. 9

30. Firing Order and Sequence of Events in Eight-Cylinder Vertical Engines.—Eight-cylinder vertical engines have the cylinders arranged in line, and thus resemble two four-cylinder engines placed end to end. This idea of a "tandem four" is carried out still further in some engines by having the cranks of the four cylinders at each end arranged as in the single four-cylinder engine, that is, with the two middle cranks 180 degrees from the end ones. The arrangement of the tandem-four eight-cylinder engine may be represented thus: 0000+0000. In other engines, the one set of four cylinders is, in effect, cut in half, and one half is placed at each end of the other set of four cylinders, as 00+0000+00. Vertical eight-cylinder engines usually have crank-shafts with five bearings; exceptions to this are the Duesenberg engine with three bearings, and the Packard and Rickenbacker engines with nine bearings.

31. An example of an eight-cylinder engine employing the tandem arrangement of the cranks is shown in Fig. 9, which is a diagram of an engine with a three-bearing crank-shaft as used in the Duesenberg car. The cranks of cylinders *1*, *2*, *3*, and *4* are arranged as in a four-cylinder engine, and the cranks of cylinders *5*, *6*, *7*, and *8* are similarly arranged. The two sets of four, however, are 90 degrees apart. The three bearings that support the crank-shaft *a* are shown at *b*, *c*, and *d*.

Upon referring to the diagram it will be seen that with a firing order of *1–5–3–7–4–8–2–6*, as used in the Duesenberg engine, if the piston of cylinder *1* is beginning its working stroke, the piston of cylinder *2* is beginning its exhaust stroke; the piston of cylinder *3* is beginning its compression stroke; the piston of cylinder *4* is starting its suction stroke; the piston of cylinder *5* is part way up on its compression stroke; the piston of cylinder *6* is part way down on its working stroke; the piston of cylinder *7* is part way down on its suction stroke; and the piston of cylinder *8* is part way up on its exhaust stroke.

32. An example of an eight-cylinder vertical engine in which the four middle cranks are arranged as in a single four-cylinder engine, and the end ones as the two halves of another

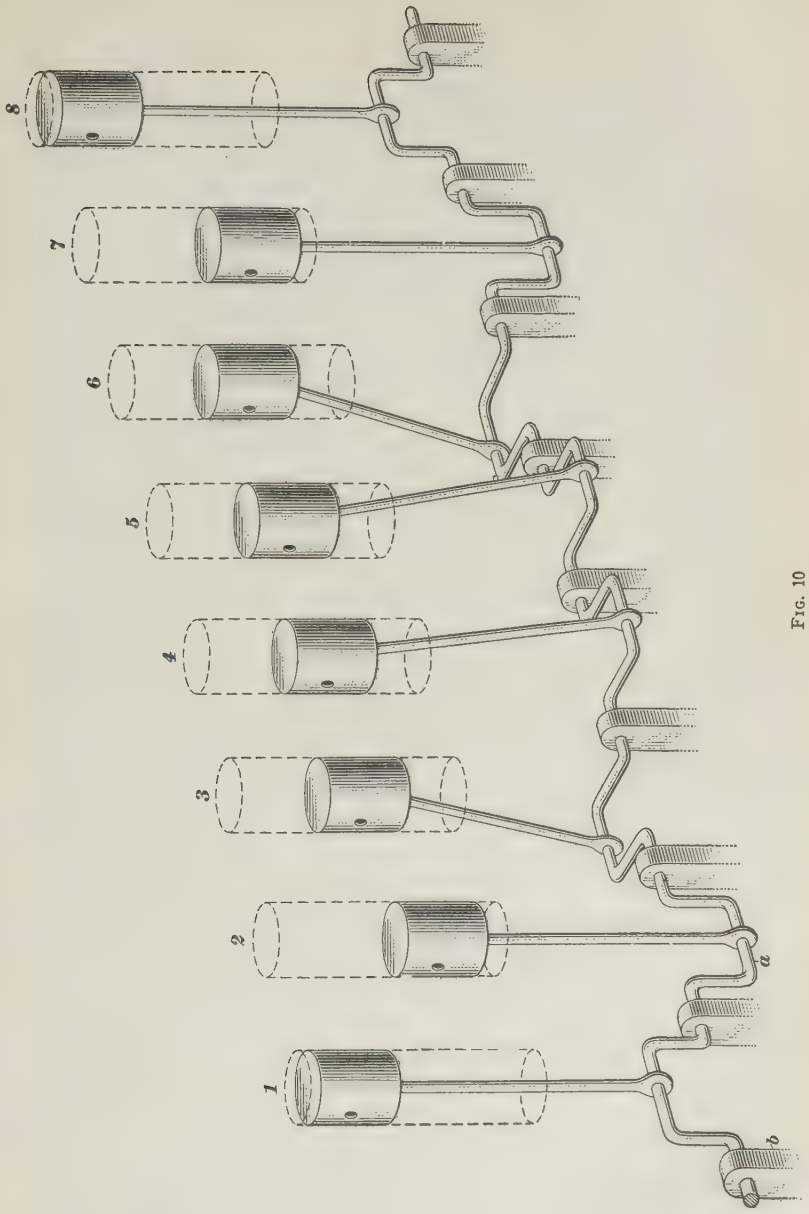

FIG. 10

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four-cylinder engine is shown in the diagram of Fig. 10. The cranks of cylinders *1* and *8*, and *2* and *7* are in the same plane, and are at right angles to the two middle pairs *3* and *6*, and *4* and *5*, which are also in the same plane. In the diagram, the cranks of cylinders *3* and *6* are shown at the left-hand side, as viewed from the front end, and the cranks of cylinders *4* and *5* are on the right-hand side. This is the crank arrangement used in the Packard, Rickenbacker, Jordan, and Lycoming eight-cylinder engines. There are several firing orders possible with the crank arrangement shown in the diagram, but only two are used in practice. As will be seen from the diagram, with a firing order of *1–3–2–5–8–6–7–4*, as used in the Packard engine, when the piston of cylinder *1* is starting its working stroke, the piston of cylinder *2* is starting its compression stroke; the piston of cylinder *3* is part way up on its compression stroke; the piston of cylinder *4* is part way down on its working stroke; the piston of cylinder *5* is part way down on its suction stroke; the piston of cylinder *6* is part way up on its exhaust stroke; the piston of cylinder *7* is starting its exhaust stroke; and the piston of cylinder *8* is starting its suction stroke.

If the cam-shaft is so constructed that the valves of cylinders *3* and *6* will reverse the operations occurring in these cylinders, that is, making the piston of cylinder *3* on its exhaust stroke and the piston of cylinder *6* on the compression stroke, the other events being undisturbed, the order of firing will become *1–6–2–5–8–3–7–4*, which is the order used in Rickenbacker, Jordan, and Lycoming engines. The crank-shaft shown at *a* in the diagram has nine bearings *b*, as is the case in Packard and Rickenbacker cars. The Jordan and Lycoming engines, however, have five bearings. Among the cars using the Lycoming eight-cylinder engine may be mentioned the Elcar, the Kissell, the Apperson, the Auburn, and the Gardner.

33. The crank arrangement used in the Hupmobile and shown in the diagram of Fig. 11 differs from that shown in Fig. 10, in that the cranks of cylinders *3* and *6* are at the right and the cranks of cylinders *2* and *5* are at the left, when viewed

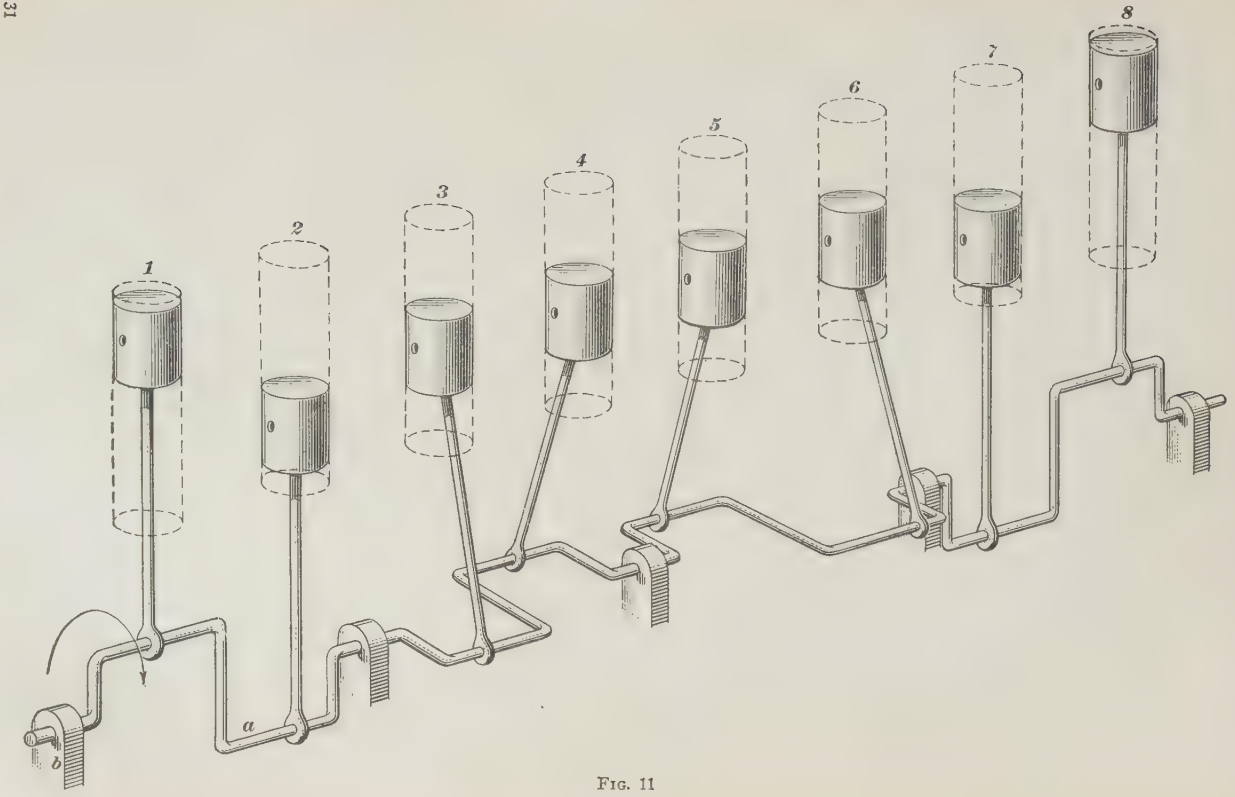

Fig. 11

from the front. With a firing order of *1–5–2–3–8–4–7–6,* as used in the Hupmobile, the events occurring in the different cylinders shown in Fig. 11 are as follows: With the piston of cylinder *1* starting down on its working stroke, piston in cylinder *2* is starting its compression stroke; piston in cylinder *3* is part way down on its suction stroke; piston in cylinder *4* is part way up on its exhaust stroke; piston *5* is part way up on its compression stroke; piston *6* is part way down on its working stroke; piston in cylinder *7* is beginning its exhaust stroke; and piston in cylinder *8* is beginning its suction stroke. The crank-shaft *a* is provided with five bearings *b*.

34. Twelve-Cylinder Arrangement.—Twelve-cylinder engines are not now being manufactured for automobile use, but a number of them are still in active service. Engines of the twelve-cylinder type have six cylinders in each of two groups that are set at an angle of 60 degrees from each other, and the pistons of each pair of opposite cylinders are connected to the same crank-pin. The crank-shaft has the same crank arrangement found in the conventional six-cylinder engine; that is, the first and sixth crankpins, the second and fifth crankpins, and the third and fourth crankpins are in line, and each pair of crankpins that are in line make an angle of 120 degrees with the other pairs, as shown in Fig. 6.

Practice varies in twelve-cylinder engines in regard to the connecting-rod arrangement. Some makers set one cylinder block slightly in advance of the other, so as to place two connecting-rods side by side on the same crankpin; other makers place the cylinders in line and use one forked and one plain connecting-rod on the same crankpin.

35. While there are a large number of possible firing orders for V-type twelve-cylinder engines, practical considerations limit these to only two for each cylinder group of six cylinders, which are 1–4–2–6–3–5 and 1–5–3–6–2–4; these two firing orders are the same as found in practice in six-cylinder engines. Employing the same firing order for each cylinder group, there are four firing orders that are practical for twelve-cylinder engines, which are:

1 R–1 L–4 R–4 L–2 R–2 L–6 R–6 L–3 R–3 L–5 R–5 L (1)
1 R–1 L–5 R–5 L–3 R–3 L–6 R–6 L–2 R–2 L–4 R–4 L (2)
1 R–6 L–4 R–3 L–2 R–5 L–6 R–1 L–3 R–4 L–5 R–2 L (3)
1 R–6 L–5 R–2 L–3 R–4 L–6 R–1 L–2 R–5 L–4 R–3 L (4)

In the firing orders given, R means the right cylinder group and L the left cylinder group, the cylinders of each group being numbered from 1 to 6, beginning at the front end of the engine.

The firing order (1) has been used in some Weidely engines, built for the trade by the Weidely Motors Co., Indianapolis, Indiana. The firing order (2) was regularly used in twelve-cylinder Ferro engines that were built for the trade by the Ferro Machine & Foundry Co., Cleveland, Ohio. The firing order (3) was regularly used in Packard and Haynes twelve-cylinder engines, and in many Weidely engines; the firing order listed under (4) was regularly used in National twelve-cylinder engines.

DETAILS OF CONSTRUCTION

AUTOMOBILE-ENGINE CYLINDERS

WATER-JACKETED CYLINDERS

36. General Construction.—The former universal practice in water-jacketed automobile-engine construction was to cast the cylinder body, the head, and the water-jacket in one piece. In the late types of engines it is common practice to make the cylinder head a separate casting and bolt it onto the cylinder proper. Only a very few makers of automobile engines adhere to the former custom. The chief object of casting the cylinder, the head, and the jacket in one piece is to avoid packed joints between the cylinder and the head and between the cylinder and the water-jacket. However, while formerly there existed considerable difficulty in securing materials from which to make a satisfactory gasket for packing the joint between the cylinder and head, the invention and development of gaskets composed of soft sheet copper and sheet brass, with sheet asbestos

between, and formed to the correct shape in dies, has overcome the former packing troubles, and this has led an ever increasing number of engine makers to adopt the detachable head.

37. The form of an automobile-engine cylinder depends on the location and arrangement of the inlet and exhaust valves. Classified according to the valve location, there are four general types of cylinders, namely the **T**-*head*, the **L**-*head*, the

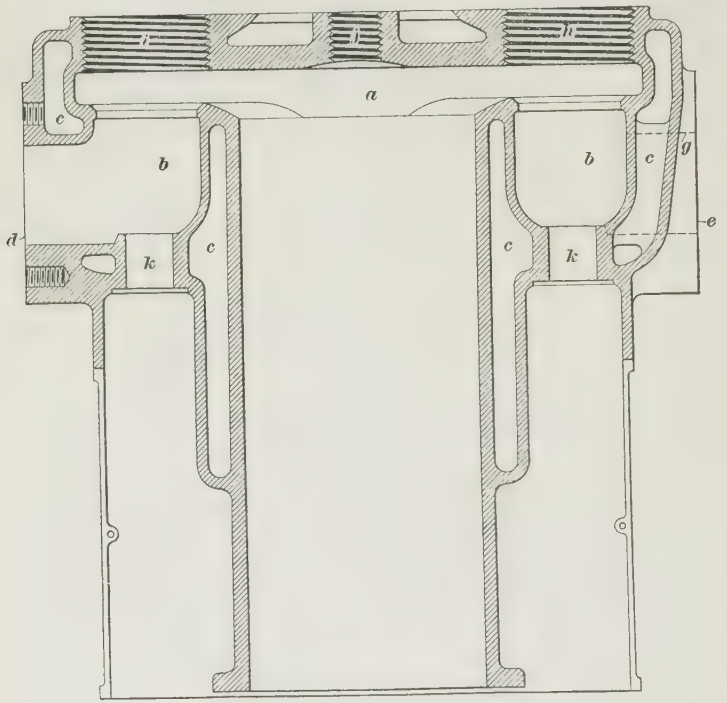

FIG. 12

I-*head*, and a combination of the **L**-head and **I**-head cylinders which is called an **F**-*head*. A somewhat uncommon construction has the valves at right angles to the cylinders.

38. T-Head Cylinders.—In engines of the **T**-head type, the inlet and exhaust valves are located on opposite sides of the cylinder, giving it, roughly, the appearance of the letter **T**. A typical **T**-head cylinder with an integrally cast head is shown

in cross-section in Fig. 12. The combustion chamber *a* and the inlet and exhaust passages *b* are surrounded by the water passages *c*. The inlet and exhaust chambers are made alike, and the valves are interchangeable. The intake pipe is connected at *d* and the exhaust pipe at *e*, chambers being cored from these openings to the valves, as shown at *f* and indicated by dotted lines at *g*. The opening on top of the cylinder at *h* permits placing the inlet valve in position or withdrawing it, and also gives access to it; a corresponding opening *i* on the opposite side is provided for the same purposes for the exhaust valve. The openings are ordinarily closed by means of *valve caps* screwed into them. Engines with T-head cylinders sometimes are provided with separate sets of spark plugs, two plugs being placed in each cylinder. When two plugs are used, they are usually screwed into the centers of the valve caps that close the openings *h* and *i*. The opening *j* is for a priming cup, and the openings *k* accommodate the valve-stem guides.

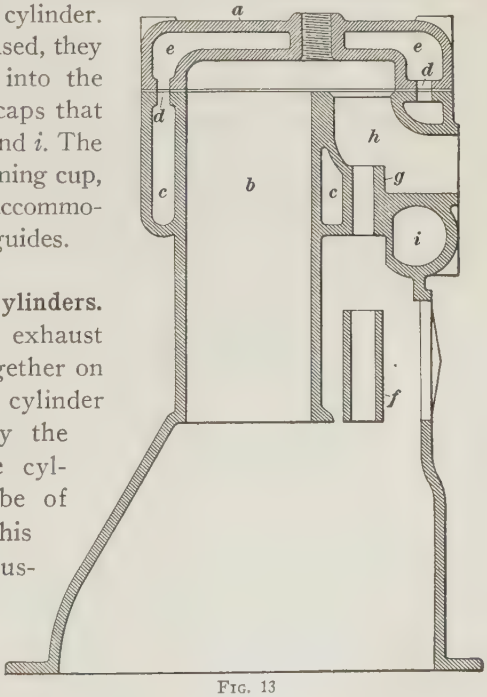

FIG. 13

39. L-Head Cylinders. When the inlet and exhaust valves are placed together on the same side of the cylinder and are operated by the same cam-shaft, the cylinders are said to be of the L-head type. This type of engine is illustrated in Fig. 13, which is a cross-section through one of the cylinders. The engine has a detachable head *a*, there being a single head common to all the cylinders. As is now quite common practice, the cylinders *b* and upper crank-case are cast in one piece.

The cylinders are surrounded by the water-jacket *c*, which is common to all the cylinders; this cylinder water-jacket com-

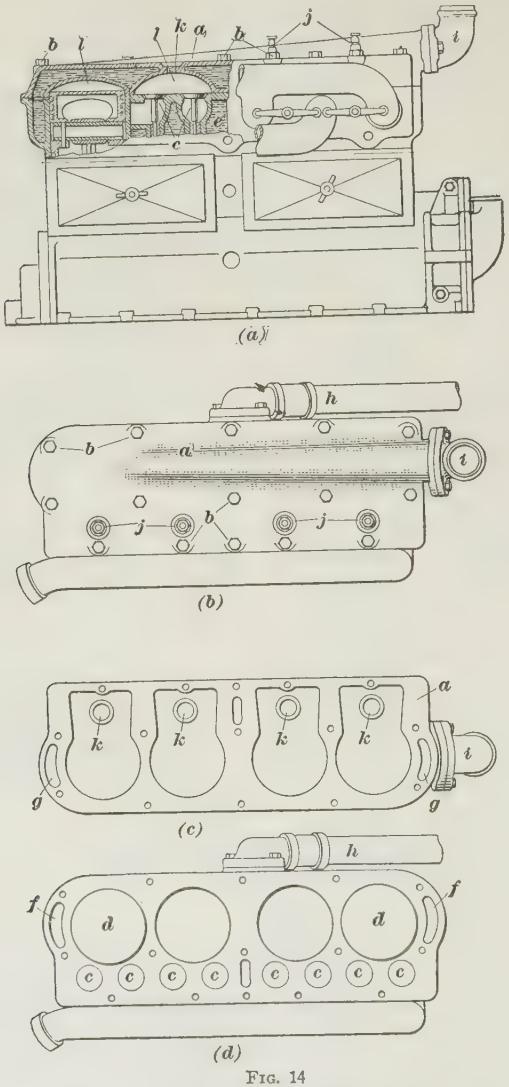

FIG. 14

municates through ports *d* with the water-jacket *c* of the cylinder head. In this engine the valve lifters move in guides *b*

cast integral with the cylinders, the guides being supplied with removable bushings. The valve-stem guides are inserted at *g* when the engine is assembled. The passage *h* leads to the exhaust pipe, and the passage *i* to the inlet pipe.

40. Another example of a detachable water-jacketed cylinder head of the L type is illustrated in Fig. 14, which shows several views of the cylinders of the Ford, Model T, engine. A side and part sectional view of the cylinders is shown in (*a*); a top view, in (*b*); and a bottom view of the head and a top view of the cylinders with the head removed, in (*c*) and (*d*), respectively. Each cylinder is of the L-head type, and the four cylinders are, as usual, cast in block. The cylinder head *a* is a single casting, which is bolted to the cylinders by fifteen capscrews *b*. When the head is removed by unscrewing these capscrews, the tops of the valves *c* and the tops of the pistons *d* are exposed, thus facilitating the processes of removing deposits of carbon, regrinding the valves, and removing the pistons and connecting-rods. As shown by the part sectional view (*a*), the valves are kept cool by the water circulating in the jacket *e* from which the water passes into the head through two passages *f*, view *d*, one at each end of the cylinder casting, corresponding passages *g*, view (*c*), being formed in the head. The water that enters the water-jacket through the pipe *h*, views *b* and *d*, passes out to the radiator through the pipe *i* attached to the top of the head, as shown. The spark plugs *j* are screwed into the openings *k*, so as to project into the combustion chambers *l* formed in the head. A copper-and-asbestos gasket is used between the cylinders and the head in order to form a tight joint.

41. In four-cylinder, six-cylinder, eight-cylinder, and twelve-cylinder engines of the L-head type, with the cylinders cast in block, and in eight-cylinder and twelve-cylinder engines having two blocks of cylinders to the engine, it is the usual practice to place the inlet valves of each pair of adjacent cylinders next to each other. Thus, considering a four-cylinder engine, or one cylinder block of an eight-cylinder engine, beginning at Cylinder 1, the valves usually come in the following

rotation: Exhaust valve 1, inlet valve 1, inlet valve 2, exhaust valve 2, exhaust valve 3, inlet valve 3, inlet valve 4, exhaust valve 4. With this construction a two-branch inlet manifold is most generally used in four-cylinder blocks, and a three-branch inlet manifold with six-cylinder blocks; many four-cylinder and six-cylinder blocks are now constructed with only a single inlet, thus dispensing with a separate inlet manifold. Some four-cylinder block-cast engines employ a four-branch inlet manifold, however. There is generally a separate exhaust outlet for each cylinder, the exhaust manifold having then as many branches as there are cylinders in the block. Occasionally the exhaust manifold is cast integral with the cylinder block, there being then only a single exhaust opening.

42. There are several advantages in having the cylinder block so constructed that no external inlet manifold is required. In the first place, the inlet passages are surrounded by the hot cooling water and are thus heated to a temperature sufficient to insure a fairly satisfactory vaporization of the gasoline in the incoming fresh charges, thereby increasing the economy of operation. In the second place, it permits of bolting the carbureter directly to the cylinder block, thus doing away with several packed joints. In the third place, it brings the carbureter into a very accessible position. A fourth advantage is the great reduction in the distances from the carbureter to the intake valves, which involves a reduced frictional resistance in the intake passages, whereby a better filling of the cylinders with a fresh charge is insured at high engine speeds.

In some cases, the intake and exhaust openings of the cylinders of L-head engines are on the one side of the cylinders, and in other cases, the intake opening or openings are on the one side of the cylinders, and the exhaust valves are on the other side.

43. The action of the fuel mixture after it enters the combustion space of an engine has considerable effect on the burning qualities of the mixture, and this fact has led to the design of an L-head combustion chamber that will produce a rapid swirling motion of the charge after it has entered the combus-

tion chamber. The swirling motion of the fuel is known as turbulence, and a turbulence combustion chamber is identified by a contour having the maximum volume over the inlet valve side of the chamber, and a very little volume or clearance above the piston head.

A type of turbulence head, known as the Ricardo head, after its inventor, is shown in Fig. 15. In this head, which is used in all models of the Waukesha engines, the space *a* above the piston *b* is of a uniform contour for a distance equal to about one-fifth the diameter of the piston, and then the upper wall of the combustion chamber slopes gradually upwards until the maximum height is reached at the spark-plug opening *c*, from which point it slopes downwards more abruptly to a point just back of the inlet valve *d*. The space *e* is thus much greater than the space *a*, and has a top the shape of a section of which is an irregular curve. The explanation offered by the designers for this type of combustion chamber is that the upward motion of the piston on its compression stroke causes a rapid swirling of the main body of the charge, as indicated by the small arrows in the illustration, and by virtue of these swirls or eddies, the entire volume of the mixture is brought into contact with the part of the mixure that was originally ignited. In other words, it is claimed that the rapid swirling of the charge distributes the flame rapidly throughout the mixture, and, consequently, causes a quicker and more thorough combustion. Definite results that are claimed for the Ricardo head are higher compression without detonation, and increased economy and power at full load.

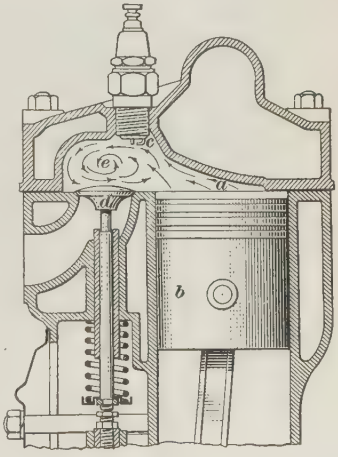

FIG. 15

Turbulence combustion chambers operating on principles similar to those described for the Ricardo head, are being built by

some American manufacturers for use in their recent model cars.

44. I-Head Cylinders.—Cylinders of the I-head type are made with the heads cast integral, and also with removable heads. When cylinders are made with integral heads, the

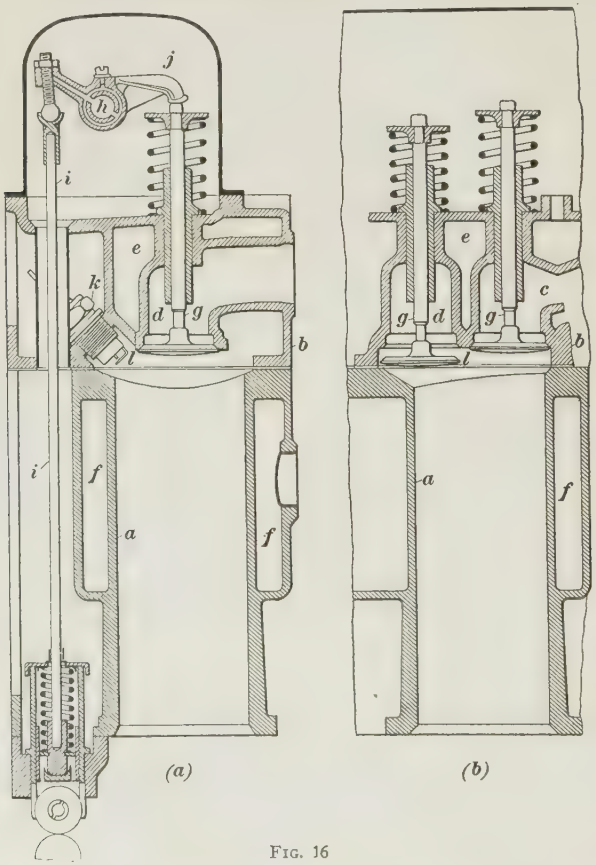

Fig. 16

cylinders must be removed from the crank-case to gain access to the valves for grinding them to their seats. With overhead valves set into a removable head, the removal of the head from the cylinders gives access to the valves, and the necessary grinding can be done at a point away from the engine.

It was formerly the custom, in some cases, to set the valves in removable cages when the cylinders were cast with integral heads. Each cage contained the valve seat and the valve-stem guide. Consequently, the valves could be ground by removing the cages. The Buick used this construction for many years, but now employs a removable cylinder head.

45. A common type of **I**-head cylinder in which the valves are set vertically in the head, and are operated by suitable mechanism from a cam-shaft in the crank-case, is shown in Fig. 16, (*a*) being a side section, and (*b*) a front section of one of the cylinders. In this engine, the cylinder *a* and the upper crank-case are cast separately, a gasket being placed at the junction of the two parts. The removable cylinder head *b* has both the inlet passages *c* and the exhaust passages *d* cast in it, both passages being surrounded by a water-jacket *e* that connects with the cylinder water-jacket *f* by means of numerous ports, which, owing to the views taken, are not shown in the illustration.

The valves *g* are operated from a single cam-shaft *h* by push-rods *i* and valve rockers *j*. The spark plug *k* is placed in the side of the cylinder head, being set at an angle, so as to project into the combustion chamber *l*.

46. A removable cylinder head of the type commonly used in **I**-type or valve-in-the-head engines is shown in Fig. 17. The exhaust valves are located at *a*, *b*, *c*, *d*, *e*, and *f*,

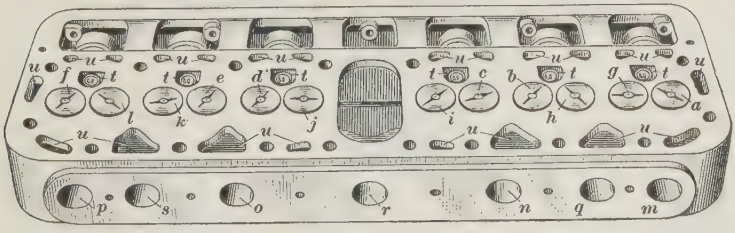

Fig. 17

and the inlet valves at *g*, *h*, *i*, *j*, *k*, and *l*. The exhaust ports are shown at *m*, *n*, *o*, and *p*, and the inlet ports at *q*, *r*, and *s*. With the exception of the two end ports *m* and *p*, each port

serves two valves, the valves being arranged as described in Art. **41.** The inner ends of the spark plugs are shown at *t*, and the water passages by which the cylinder-head jacket and the cylinder water-jackets are connected, are shown at *u*. This valve arrangement is very convenient when it is necessary to do any work on the valves, as the entire overhead mechanism may be carried to a work bench.

47. Other arrangements of the valves of I-type cylinders have been made from time to time. For example, the construction shown in Fig. 18 has been used in some engines employed for racing purposes. The valves *a* and *b* are set at an angle directly in the cylinder head, which is cast integral with the cylinder block, and are operated by the valve rockers *c* and *d* from an overhead cam-shaft *e*. When it is necessary to grind the valves of an engine of this type, the cylinder block must be removed from the crank-case.

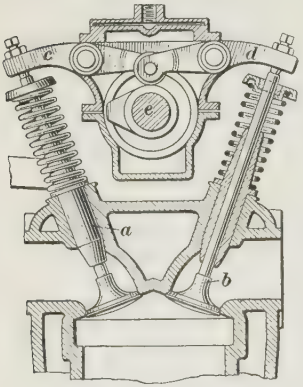

FIG. 18

48. F-Head Cylinders.—The F-head type of cylinder, in which the inlet valve is located in the head and the exhaust valve at the side, is sometimes used. An example of this type of cylinder is found in Reo passenger cars and trucks. A cross-section through one of the cylinders of the Reo six-cylinder engine is shown in Fig. 19. The inlet valve *a* is placed in the removable cylinder head *b*, and the exhaust valve *c* is placed at one side of the cylinder. The inlet valves and the valve rockers *d* are enclosed in a dust-proof cap *e*. The inlet from the carbureter is at *f*, and the exhaust manifold is shown at *g*. The water inlet of the water-jacket of the cylinders and the head is shown at *h*, and the top water outlet at *i*. The exhaust valves are operated directly from the cam-shaft *j* by the valve lifters *k*.

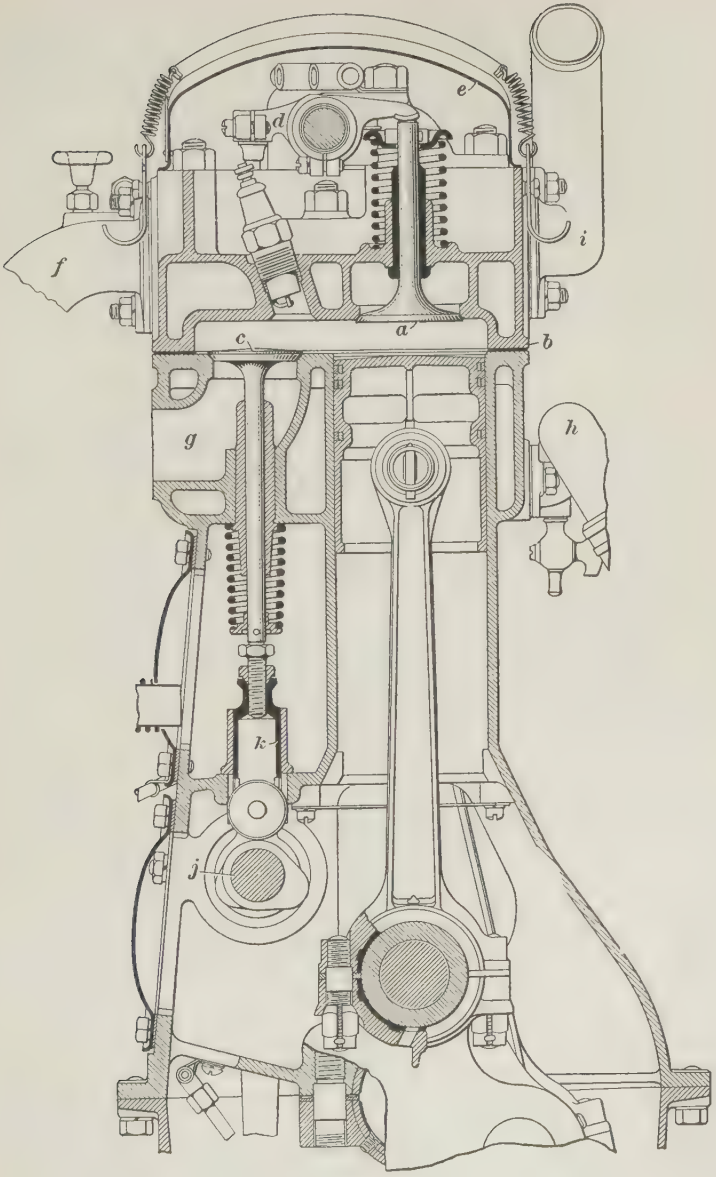

Fig. 19

49. The **T**-head, **L**-head, **I**-head, and **F**-head cylinder types are those most commonly met with in practice, but other designs have been, and are, used to a slight extent. Among these may be mentioned a model of the Duesenberg engine that has proved very successful in racing-car work. In this engine the valves are horizontal, lie on the same side of the engine, and are operated by long vertical valve rockers, the lower ends of which are rocked back and forth by the usual horizontal cam-shaft. The term **H** head is sometimes used in connection with cylinders of this type.

AIR-COOLED CYLINDERS

50. The internal construction of an air-cooled cylinder is the same as that of a water-cooled cylinder; also, the arrangement of the valves and other mechanism is similar. The external surface of an air-cooled cylinder, however, is extended, or increased, by various means, usually by the use of thin heat-radiating flanges, or ribs, cast integral with the cylinder walls or fitted to them. These ribs, or flanges, serve to conduct the heat from the cylinder walls, the heat being absorbed and carried away by the air that comes in contact with some of the flanges.

51. The best-known example of the air-cooled cylinder is that used on the Franklin automobile. One of these cylinders is shown in Fig. 20, (*a*) being a side view, and (*b*) a top view. The valve-operating mechanism, which fits on the top of the cylinder, has been removed in order to show the construction of the cylinder more clearly. A large heat radiating surface is obtained by the use of vertical copper flanges *a* that are cast in the wall of the cylinder *b*. The flanges are spaced about $\frac{3}{16}$ inch apart around the entire circumference of the cylinder, and project radially outward a distance of about 1 inch. In previous models of the Franklin engine, the flanges were made of steel, and a cylindrical air jacket surrounded each cylinder with its flanges, but in the model shown, the outer ends of the flanges are bent over so as to form air passages around the cylinder, through which the cooling air is forced by a fan.

The air is thus brought into close contact with the flanges, which conduct the heat from the cylinder walls. An air hood fits over the top of the engine and is joined to another hood

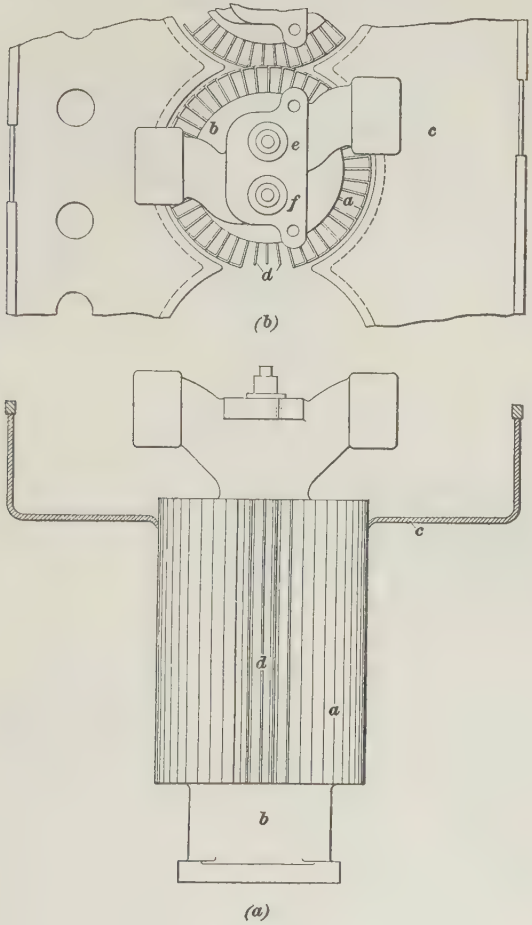

FIG. 20

that is around the fan, so that all of the air drawn in by the fan is forced directly on to the top of the cylinders. The lower section of the hood, a part of which is shown at *c*, fits closely around the cylinders at the sides and causes the air to

pass through the openings formed by the flanges *a*. The flanges are partly cut away at the rear of each cylinder as shown at *d*, so as to permit the cylinders to rest closely together and not leave a space between them, where the air might escape without coming in contact with the flanges.

The cylinder shown is of the I-head type. The valves operate in the guides *e* and *f*, and are operated by push rods and rocker-arms. The cylinder head, into which the valves seat, is cast in one piece with the cylinder, it being necessary to remove the cylinder to clean the carbon or regrind the valves.

CONSTRUCTIONAL DETAILS

CRANK-CASES

52. General Construction.—The casing, or housing, of an automobile engine that encloses the cranks and crank-shaft, and, frequently, other moving parts as well, is called the crank-case. Besides forming a housing for most of the working parts, it also serves as a frame, or bed, that supports the crank-shaft and cylinders; and, usually, the lower part serves as a receptacle for the oil used in the lubrication of the engine. When the crank-case is separate from the cylinders, it is generally cast of aluminum or an alloy of aluminum, although in rare cases manganese bronze, pressed steel, or cast iron is employed. Aluminum is used on account of its light weight in comparison with its strength. When the crank-case is cast in one with the cylinder block, it is naturally of the same material as the cylinders, which in practically all cases is cast iron. The size of a crank-case depends entirely on the design of the engine, but in any event it must be large enough to allow the cranks to rotate freely within it and strong enough to support the cylinders and the crank-shaft.

Crank-cases are usually divided horizontally into halves, which are bolted together, although the upper half is sometimes divided vertically.

53. Typical Crank-Cases.—The most common type of automobile-engine crank-case is one in which the case is divided horizontally into halves and the crank-shaft bearings are supported entirely from the upper half. This type of crank-case

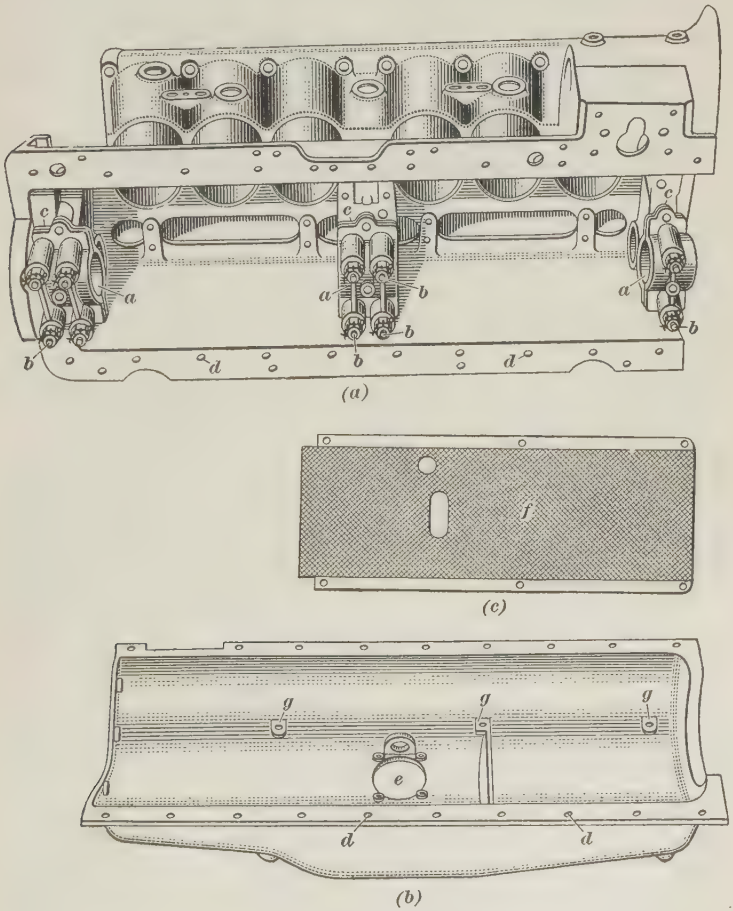

FIG. 21

is illustrated in Fig. 21, which shows the upper and lower parts of the crank-case used on one make of a six-cylinder engine. In (*a*) is shown a view of the upper half with the moving parts removed, such as would be obtained by a person lying on

his back beneath the engine and looking upwards after the lower half is taken off. In (*b*) is shown a top view of the lower half of the crank-case. There are three crank-shaft bearings *a* in this case. The lower half of each bearing is a cap held in place by capscrews *b*, which are screwed into the supports *c*. The capscrews are prevented from turning under the influence of vibration by having stiff wire or cotter pins passed through them and their castellated nuts.

The lower half of the crank-case is attached to the upper half by means of bolts that pass through the holes *d*. The bottom of the case, view (*b*), beneath the oil troughs, is used as an oil well, or reservoir, whence oil is pumped directly to the working parts of the engine. The oil strainer that cleans the oil on its way to the oil pump is placed in the opening *e*. The baffle plate or screen *f*, view (*c*), fits into the crank-case directly under the connecting-rods, and removes any large particles of dirt from the oil as it passes into the oil reservoir underneath. The plate *f* rests on the lugs *g*, view (*b*).

54. Most crank-cases are made with an enlarged extension at the rear end, which extension encloses the flywheel and clutch; the transmission housing, in the case of unit power plants, is then bolted to the rear of the crank-case extension. In a few cases of unit power plants the flywheel and clutch are not entirely enclosed, in order to give free access to the clutch without having to remove the transmission.

55. The crank-case shown in Fig. 21 is used with the so-called pressure oiling system. In the splash oiling system, the crank-case is fitted with an oil pan placed above the oil reservoir and underneath the cranks. The engine shown in Figs. 1 and 2 employs the splash system of lubrication, and an inside view of the crank-case *d*, removed from the engine, is shown in Fig. 22. By referring to the inside view, it will be seen that the splash pan *a* has four troughs *b*, which, when the crank-case is in place on the engine, are directly beneath the four cranks, and are at such a height that a projection on the end of the connecting-rod passes through them at each revolution of the crank-shaft. Oil is delivered to the troughs by

means of piping from the oil pump b', Fig. 3, and is kept at a uniform level in the troughs by the holes c, Fig. 22. Excess oil from the troughs, as well as that which drains from the engine, passes through the holes c and d, and into the oil reser-

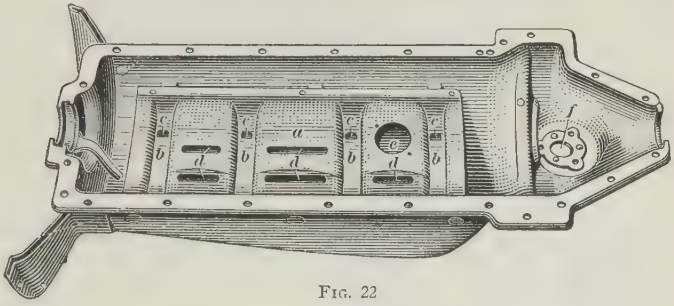

FIG. 22

voir in the bottom of the crank-case. The opening e allows for the insertion of the float of the oil gauge, shown at y, Fig. 3, and the opening f, Fig. 22, is provided for the bushing through which the drive shaft of the oil pump b', Fig. 3, passes.

56. In most cases the engine supports, that is, the brackets by which the engine is supported on the frame of the car, are an integral part of the upper crank-case, or are bolted thereto. In a few cases, however, the supports are part of the

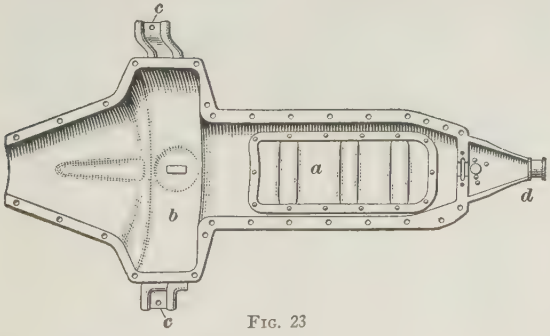

FIG. 23

lower crank-case. The best-known instance of this practice is found on the engine of the Model T Ford car, the lower crank-case of which is shown in top view in Fig. 23. The crank-shaft bearings are carried by the upper half of the case, which

is of cast iron and is cast integral with the four cylinders. The lower half is of pressed steel and is bolted to the upper half. An inspection plate *a* is bolted to the bottom half and can be

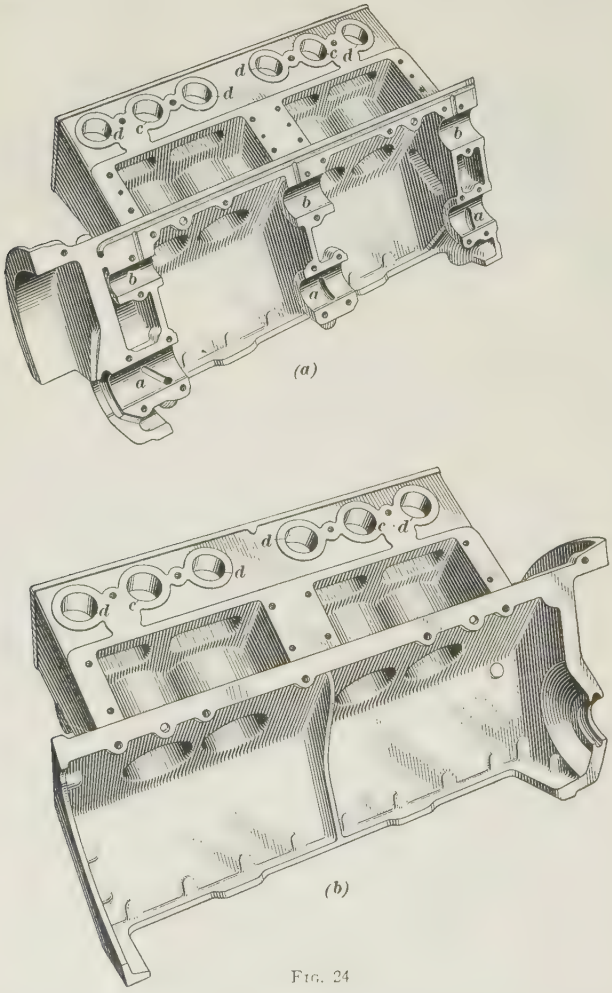

FIG. 24

removed for inspection purposes. The rear end *b* encloses the flywheel and transmission gears and is supported by two arms *c* that are fastened to the case. The front end is supported at a

single point *d*, thus forming the three-point suspension method of support.

An example of a vertically divided crank-case is found in eight-cylinder engines built by the Northway Motor and Manufacturing Company, Detroit, Michigan, for the trade. In these engines half the upper crank-case and one block of four cylinders are cast as a unit, as shown in Fig. 24, where in (*a*) is illustrated the left-hand block and in (*b*) the right-hand block. The three main bearings *a* and three cam-shaft bearings *b* are carried by the left-hand block. In assembling the engine the two blocks are rigidly bolted together. The cylinders are of the L-head type, with a removable cylinder head for each block of four cylinders; each cylinder block has two inlet ports *c* and four exhaust ports *d*.

57. Crank-Case Breathers.—The crank-cases of four-cycle engines are provided with an opening to which is attached a pipe called a breather, which allows the escape of air and hot gases. With the four-cycle engine, an air-tight crank-case would not be advantageous, because where the hot gases leak past the piston rings into the crank-case, there would be a tendency to overheat the bearings and to burn the oil, and through imperfect lubrication rapid wear of the engine would result. The breathers prevent this by allowing these hot gases to escape. In addition to this, the pressure in a closed crank-case of a multiple-cylinder engine varies because of the movements of the reciprocating parts; hence, another use of the breather is to relieve this pressure variation and keep it the same at all times. Varying pressures in the crank-case might interfere with the proper working of the lubricating system by forcing the oil out of the crank-case through the joints or bearings. Crank-case breathers are usually called oil fillers as they serve the purpose of oil-filling tubes, through which the lubricating oil is poured into the lower half of the case.

Breathers for four-cylinder and six-cylinder engines are usually located in the upper part of the crank-case as shown at *f'*, Fig. 2, although they are sometimes located on the cylinder

head. Occasionally they are cast integral with the case, but more often they are separate fittings bolted on. With V-type eight-cylinder and twelve-cylinder engines, breathers are fitted in various ways. Sometimes they are placed on top of the crank-case, sometimes on the timing-gear case, and also on top of the cylinder blocks, a passage in that case being cored out through the cylinder block to the crank-case; the passage is then partly closed at the top by a removable cap. As will be seen from Fig. 2, the cap of the breather *f'* does not fit tightly, but has an air space between it and the upright pipe.

MANIFOLDS

58. Inlet Manifolds.—While many of the modern four-cylinder and six-cylinder engines with block-cast cylinders do not require any inlet manifold, because the carbureter is bolted directly to the cylinder casting, yet the design of many others requires the use of such a manifold. With V-type eight-cylinder and twelve-cylinder engines, where there are two cylinder blocks of four cylinders and six cylinders each, respectively, an inlet manifold is required. In many engines of this kind there is one inlet to each cylinder block, and hence the inlet manifold has two branches to the cylinder block and one branch for the carbureter. In other designs of V-type eight-cylinder and twelve-cylinder engines there is more than one inlet for each cylinder block, and consequently, if an ordinary single carbureter is employed, the inlet manifold has more than two branches for the cylinders and a separate branch for the carbureter. When a so-called duplex carbureter is employed with an eight-cylinder or twelve-cylinder engine, a separate manifold is generally used for each side of the carbureter, which may have one or more branches to the cylinder block and one branch to the carbureter.

Inlet manifolds are usually heated by means of a jacket through which exhaust gases or hot water are passed, or the manifold is combined with the exhaust manifold and is heated directly from it. The object of heating the inlet manifold is to prevent as much as possible the condensation of the gasoline

in the incoming fresh charge, and to assist further vaporization of the fuel.

In the design of inlet manifolds for automobile engines, the most important considerations are that the incoming fresh charge be equally divided among the various cylinders and that the mixture going to the cylinders be of uniform richness. These problems are comparatively simple with four-cylinder four-cycle engines, because the lengths of the branches, or pipes, running to the inlet valves can easily be made equal.

59. Inlet manifolds for **V**-type eight-cylinder and twelve-cylinder engines are made both with and without a heat jacket. When such manifolds are water-jacketed, it is the common

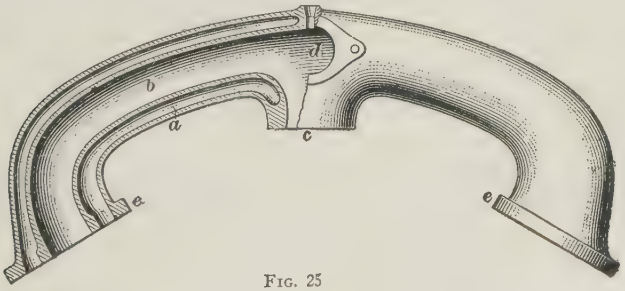

FIG. 25

practice to make the manifold also serve as the top water outlet from the two cylinder blocks to the top of the radiator; such a water-jacketed inlet manifold is shown partly in section and partly in elevation in Fig. 25. It consists virtually of two pipes, the one inside the other, the annular space *a* between the two forming the water-jacket for the inlet manifold *b* to which the carbureter is bolted at *c*. The outlet of the water-jacket *a* to the top of the radiator is at *d*. The flanges *e* are placed on the removable cylinder heads of the engine and are firmly bolted to them.

60. Exhaust Manifolds.—The manifold that conveys the exhaust gases to the exhaust pipe is usually in the form of a pipe of large diameter that communicates with the various exhaust ports and is connected in the rear to the exhaust pipe

that runs to the muffler. The manifold usually slopes downwards at its rear end, at an angle approximating 45 degrees where it is joined to the exhaust pipe.

The exhaust manifold of four-cylinder engines usually has three branches. In six-cylinder engines with individually cast cylinders, as in the case of the Franklin air-cooled engine, there are six outlets from the exhaust manifold. In the six-cylinder block-cast engines the exhaust manifold sometimes has only four branches, in which case two branches each serve two cylinders, and two branches each serve one cylinder. With V-type eight-cylinder and twelve-cylinder engines, each cylinder group has its own exhaust manifold, which usually is connected to its own exhaust pipe and muffler. In vertical-eight engines, different forms of exhaust manifolds are employed; in some cases exhaust passages being formed with the cylinder block so that only five branches are necessary, while in other cases, two exhaust manifolds, each serving four cylinders are employed.

61. Combined Intake and Exhaust Manifolds.—The gasoline obtainable in the open market at present contains a large percentage of constituents that have a rather high boiling point, and which, consequently, do not vaporize at ordinary atmospheric temperatures, or even at the temperatures obtaining in water-jacketed inlet manifolds. To insure proper vaporization

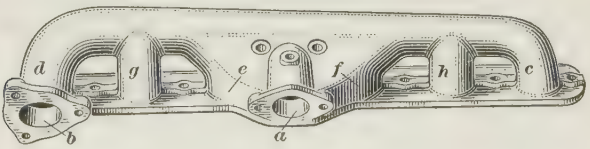

FIG. 26

of such heavy constituents of the fuel, thereby securing better fuel economy, some engines regularly built for the trade are equipped with combined intake and exhaust manifolds. In such manifolds the intake part of the manifold is heated to a fairly high temperature by the exhaust part, thereby heating the fresh charges passing through the intake part. Combined intake and exhaust manifolds are also built for a large number

of engines fitted originally with separate manifolds, by several concerns specializing on this line of work.

62. An example of a combined intake and exhaust manifold is shown in Fig. 26. This manifold, which is used on the Stutz engine, has the inlet opening at *a*, and the exhaust opening at *b*. The end connections, one of which is shown at *c*, and the other of which is hidden by the bent section *d*, and the connections *e* and *f* lead to the exhaust ports of the cylinder

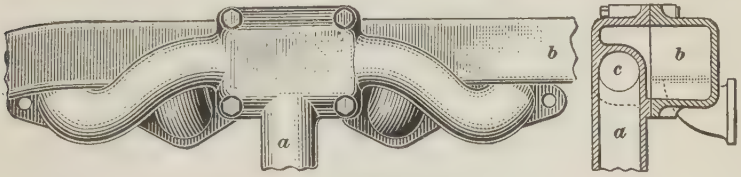

FIG. 27

block, while the connections *g* and *h*, and the center connection, not shown, lead to the inlet compartments.

In Fig. 27 is shown what is known as a hot-spot intake manifold, as used on a large number of automobile engines. The intake manifold *a* and the exhaust manifold *b* are brought together at the center so that the hot exhaust gases sweep over the upper wall *c* of the inlet manifold; the incoming fresh charge strikes directly against the heated upper wall *c* and thereby the gasoline is satisfactorily vaporized.

GASOLINE AUTOMOBILE ENGINES
(PART 2)

DETAILS OF CONSTRUCTION

RECIPROCATING AND ROTATING PARTS

PISTONS

1. Construction.—The pistons used on automobile engines are made hollow to receive one end of the connecting-rod. Such pistons are of the so-called trunk type, being constructed in this way so as to make a shorter and more compact engine. The piston consists of a hollow cylindrical iron or aluminum alloy casting that is carefully machined in order to have a good working fit in the cylinder. The diameter of the piston is slightly less than the bore of the cylinder. If it were the same, the piston would stick when it became heated, because the piston becomes hotter and expands more than the cylinder, which is kept relatively cool by the water-jacket. An air-tight joint is made between the piston and the cylinder wall by means of piston rings that are placed in grooves surrounding the piston.

The piston is connected to the crank-shaft by the connecting-rod, and the connecting-rod is joined to the piston by means of a piston pin, or wristpin. In some cases, the small end of the connecting-rod is fastened to the piston pin, and in such cases, the pin is free to turn in the piston casting. In other cases, the piston pin is loose in the small end of the connecting-rod, and is then either fastened in the piston casting, or is free

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to turn. When the pin is free in both the piston and the connecting-rod, it is said to be *floating*.

2. Piston Rings.—On account of the mechanical impossibility of making a solid piston so that it will have an air-tight and at the same time a free-running fit in the cylinder under the conditions met in automobile practice, elastic, expansible piston rings made usually of close-grained, gray cast iron, are used to make a tight joint. For this purpose the piston is

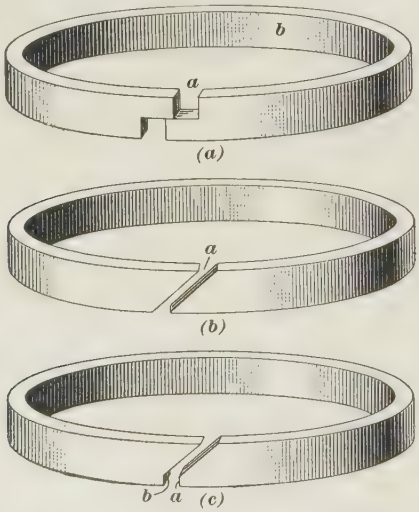


FIG. 1

grooved and rings of the form shown in Fig. 1 are sprung, or snapped, into the grooves. These rings are commonly called *snap rings*. They are split, or cut, in two on one side so that they may have an expansive elastic action to press them close against the cylinder walls. Piston rings are made of such diameter that they press lightly against the wall throughout their entire circumference. The joints in the ring where it is split are made in several different forms, some of which are shown in the illustration.

3. A piston with the rings in place is shown in Fig. 2. The three rings *a* form a tight joint between the piston and

the cylinder wall. These rings are parted, as shown at *b*, so that they can spring outwards against the cylinder wall and prevent the gases from escaping from the combustion chamber into the crank-case. Each of the grooves in which the rings are set, except the lower one, is made with square corners. The lower corner *c* of the groove in which the lower ring fits, in this particular case is beveled at an angle of 45° instead of being square and thus forms an oil groove, or wiper groove. The sharp edge of the lower ring, on the downstroke of the piston, scrapes or wipes all excess oil on the cylinder wall into

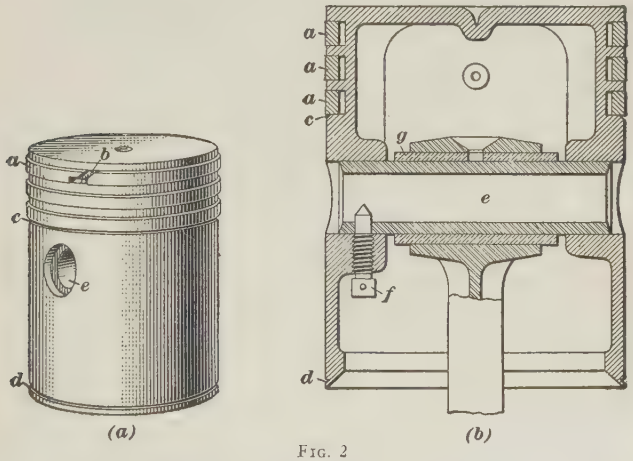


FIG. 2

this wiper groove, whence the oil is conveyed through holes to the piston pin to assist in its proper lubrication. An oil groove *d* is turned on the bottom end of the piston for collecting the oil that is splashed upwards from the crank-case and distributing it over the cylinder wall. The beveled groove *c* and the lower oil-ring groove *d* are not used in all pistons.

4. Piston Pin.—The piston pin *e*, Fig. 2, is hollow, is made of steel tubing case-hardened and ground on the outside after hardening, and is secured in the piston casting by means of a setscrew *f*, which is prevented from backing out by a short wire that is pushed through a hole in the head of the screw. The setscrew prevents the piston pin from turning in the piston

and from moving endwise and thus scoring the cylinder wall. The middle part of the pin *e* fits in a hard bronze bushing *g* in the upper end of the connecting-rod. There are other ways of fastening the piston pin to the piston.

CONNECTING-RODS

5. Connecting-rods for automobile engines are usually made of drop-forged steel and are of I-beam cross-section. The lower, or crank-shaft, end of the connecting-rod is made large and contains a bearing for the crankpin; the upper end is smaller and either forms a bearing for the piston pin or is rigidly secured to it. For the engines of racing cars, connecting-rods having a tubular cross-section are frequently used, on account of their light weight; such connecting-rods are generally hand-forged and machined all over, but are so expensive to make as to prohibit their use except where cost is no consideration.

6. A very common type of connecting-rod is shown in Fig. 3. It is of I-shaped section, the large end *a* being split at right angles to the rod through the center of the bearing. A

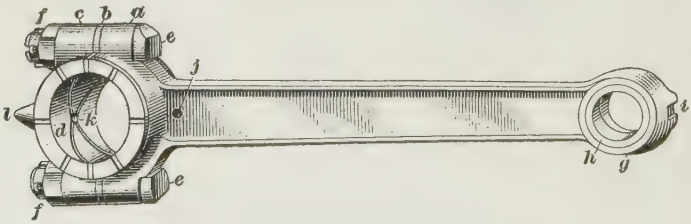


FIG. 3

so-called *shim*, or distance piece, *b* is then placed between the connecting-rod end *a* and the cap *c* and the bearing is bolted together, with the bronze-backed Babbitt-metal bushings *d* in place, by the bolts *e* and castellated nuts *f* secured by cotter pins. The smaller end, or piston-pin end, *g* has a machined hole lined with a hard bronze bushing *h* pressed into place. In the engine using a splash lubrication system, oiling of the

piston pin is provided for by milling a recess *i* into the connecting-rod and drilling a $\frac{1}{4}$-inch hole from this recess through the bushing *h*. Two spiral oil grooves, one of which connects to the hole mentioned, are cut into the bushing *h* and serve to distribute the oil over the piston pin. Proper oiling of the crank-

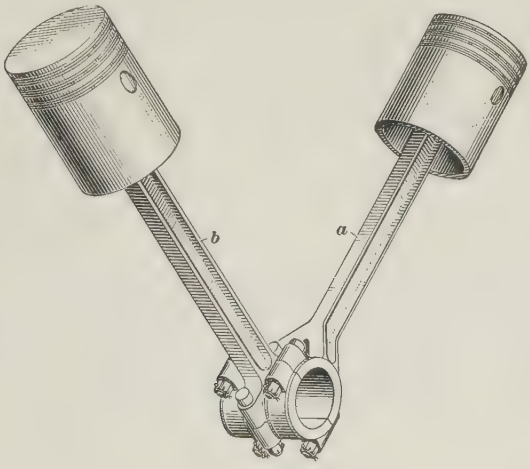


FIG. 4

pin end is provided for by drilling a hole *j* through the connecting-rod and upper bushing *d*, and also a hole *k* from the splasher *l* through the lower bushing *d*, which holes communicate with oil grooves cut into the bushing. The splasher *l*, at each revolution of the crank-shaft, dips into oil carried in a trough below the connecting-rod.

7. Several methods of connecting the pistons of opposite cylinders of **V**-type engines to the same crankpin have been in use in the past, but the present practice is to have the cylinders of the two blocks directly opposite each other, and to fork the one connecting-rod, as at *a*, in Fig. 4. The forked connecting-rod carries a long bushing split longitudinally, the one half being in the connecting-rod and the other half in the cap. The second connecting-rod is not attached to the crankpin itself, but fits between the fork of the rod *a* over the outside of the bushing. Consequently, while the crankpin turns completely

around inside the bushing of the forked connecting-rod, the other connecting-rod only rocks on the outside of the bushing during the revolution of the crank-shaft. The angle through which rocks the connecting-rod that fits inside the forked rod is quite small, ranging from about 12 degrees to 20 degrees, depending on the design of the engine.

CRANK-SHAFTS

8. Construction.—Crank-shafts for automobile engines are made of special grades or alloys of steel, so that they may be as light as possible and yet be strong enough to resist the twisting and bending action to which they are subjected, the bearing part being made sufficiently ample to withstand the wear due to continuous rotation at high speed. Automobile-engine crank-shafts are most frequently made in one piece,

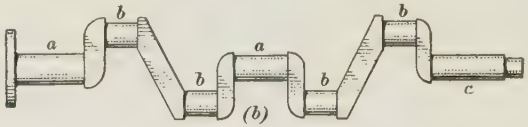


FIG. 5

and are either machined from a rough flat forging or drop-forged in dies.

Crank-shafts for four-cylinder engines are supported by two, three, or five bearings; crank-shafts for eight-cylinder **V**-type engines usually have three bearings. The same form of crank-shaft is usually used for four-cylinder and eight-cylinder **V**-type engines. An exception to this is the crank-shaft used in the late model Cadillac engines.

Crank-shafts for six-cylinder engines are supported by three, four, or seven bearings. Eight-cylinder vertical-type engines are made with three, five, or nine bearings. A typical crank-shaft is shown in Fig. 5, the shaft being for a four-cylinder engine. The journals that turn in the bearings are shown at *a*, and the crankpins at *b*.

9. Counterbalancing.—Crank-shafts of the form shown in Fig. 5, when properly made, are in perfect static and running

balance when considered by themselves alone. They are subject to distortion, however, by the action of centrifugal force and by the influence of the weight of the connecting-rods and piston. The distorting forces, and consequent actual bending of the crank-shaft, are small at low speeds of rotation, but as a doubling of the rotative speed increases the centrifugal force four times, it can readily be seen that crank-shafts of the form shown in Fig. 5 cannot obtain very high rotative speeds without excessive distortion and subsequent unbalancing of the crank-shaft, thereby setting up severe vibrations. To permit of higher rotative speeds, as for engines making over 3,000 revolutions per minute, crank-shafts are *counterbalanced,* that

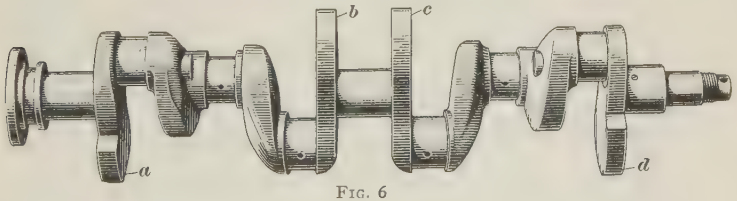


FIG. 6

is, counterweights are provided on the crank-shafts at the proper points so that the various forces tending to cause vibration will be balanced.

An example of the counterbalanced crank-shaft is shown in Fig. 6. The crank-shaft which has three bearings, has counterweights *a, b, c,* and *d* welded to the crank-flanges at points directly opposite the crankpins. In some counterbalanced crank-shafts the balance weights are bolted in place, whereas in others they form a part of the original drop forging.

FLYWHEELS

10. In a previous Section in connection with the explanation of the four-cycle engine, it was pointed out that only one of the four strokes making up the cycle is a working stroke. This means that in a single-cylinder engine, there will be a turning effort exerted on the crank-shaft on one stroke only, and there will be three idle strokes before the next working

stroke begins. Even in a four-cylinder engine, wherein the working strokes of the different cylinders are so proportioned as to give an impulse to the crank-shaft every half-revolution, the connecting-rod and crank are in a straight line in each cylinder at the end of each working stroke, and there will be no tendency for the crank-shaft, in itself, to rotate further. In order to have a practical working engine, it is necessary to provide some means of storing up the mechanical energy developed in the crank-shaft during the working stroke, and to utilize this energy to maintain a uniform rotation of the crank-shaft between working strokes. The means employed in the gasoline engine for storing up the energy produced by the

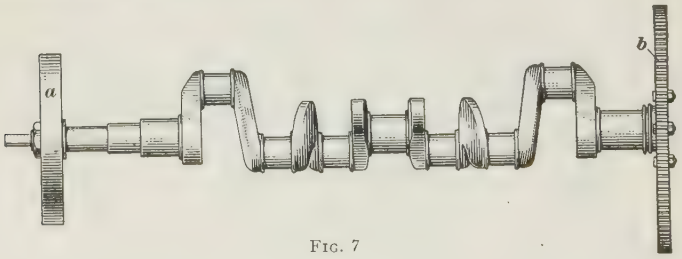


FIG. 7

working stroke of the engine is by a flywheel. When the flywheel, which carries most of its weight, as a rule, in its rim, is set in motion, it will continue to rotate to the extent necessary to cause the operations to occur regularly in the engine, and thus give a uniform or smooth application of power to the external system. Even with a six-, eight-, or twelve-cylinder engine, in which the working strokes overlap, a flywheel is necessary in order to maintain a smooth regular running of the engine, and make the crank-shaft turn over easier in starting the engine. The flywheel, however, is made lighter as the number of cylinders is increased.

The flywheel usually forms a part of the friction clutch used in automobiles, and, in the case of the Ford engine, the flywheel carries the permanent magnets of the magneto, as well as the planetary transmission assembly. Some engines employ two flywheels, the double-flywheel construction used in Rickenbacker cars being shown in Fig. 7. It will be seen that the

two flywheels *a* and *b* are much lighter than the single large flywheel generally used. By using a light flywheel at each end of the crank-shaft, the weight of the shaft will be evenly distributed over the main bearings. Furthermore, as the amount of twist or deflection depends upon the length of the shaft, the amount of twist in the shaft, when a single flywheel is used, is different in case of the explosion in the cylinder nearest the flywheel and in the cylinder the most remote from the flywheel. The addition of the front flywheel, therefore, causes a twist toward the front as well as toward the rear, and if the front flywheel is properly proportioned, the tendency of the crank-shaft to vibrate is much less than when a single crank-shaft is used. In fact, in the engines employing the two-flywheel construction, the vibration period is raised to a point higher than the critical speed of the engine.

VIBRATION DAMPERS

11. Flywheel Type.—A vibration damper is a device that is used on some engines to overcome the vibrations to which practically all engines are subject at certain so-called critical speeds. The most common type of damper consists of a small flywheel that is carried between two friction disks mounted on and driven by the engine crank-shaft. There is no positive connection between the crank-shaft and the damper flywheel, the flywheel being driven entirely by the friction of the two disks, which are held tight against it by one or more springs, in the manner of the automobile friction clutch. When the engine is started, the damper flywheel is set in motion, and having started to rotate, its inertia or momentum causes it to resist any tendency to vary its motion. Consequently, any sudden variation in the movement of the front end of the crank-shaft, such as might be caused by the "whipping" of the shaft, will be resisted by the flywheel damper, and cause the damper flywheel to slip between the frictional disks. The friction between the flywheel and the disks on the crank-shaft will lessen the tendency to vibrate, and will also silence the noise of any vibration that may occur.

12. The damper used on the Studebaker car is shown in section in Fig. 8. The small flywheel *a* is made in two sections that fit between the friction disks *b*, and with which they are held in contact by means of springs, one of which is shown at *c*. The disks *b* are fastened to the member *d*, which is carried on and driven by the hub of the overrunning starter clutch *e*. The

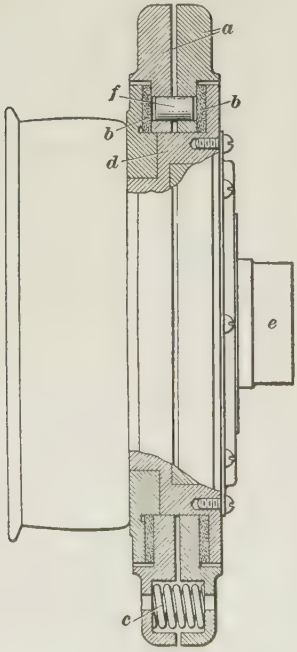


FIG. 8

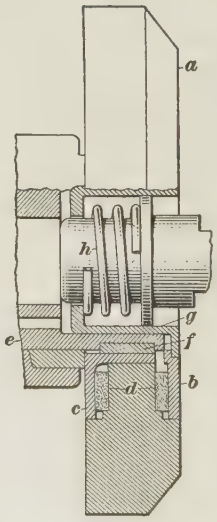


FIG. 9

pin *f* that passes through both members of the flywheel *a* prevents motion of one half of the flywheel relative to the other half. This type of damper was used also on early models of the Packard single-eight engines.

13. Later models of the Packard cars use the type of vibration damper shown in Fig. 9. The flywheel *a* in this case is solid, and there are two flanges *b* and *c* carrying the frictional disks *d*. The inner flange *c* is carried on the hub *e* of the silent-chain sprocket, and is positively driven from the

hub by the key *f*. The outer disk *b*, which is movable in the direction of its axis, but has no rotative motion relative to the hub *e*, is held firmly against the flywheel *a* by the webbed collar *g* and the spring *h*.

14. Lanchester Harmonic Balancer.—Another device that has for its purpose the elimination of vibration is the Lanchester harmonic balancer used on four-cylinder models of the Willys-

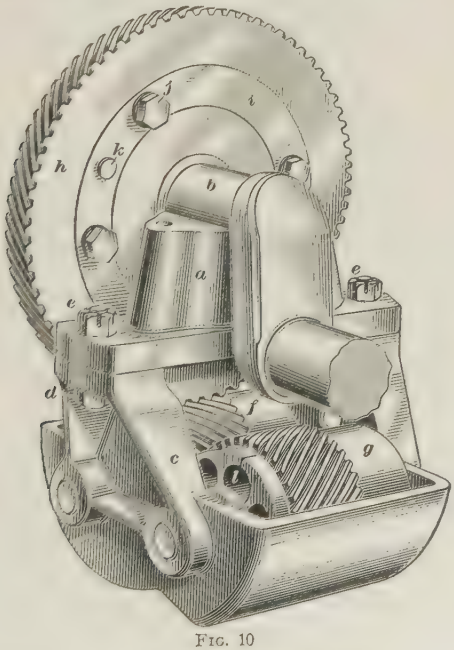


FIG. 10

Knight engines. This device reduces vibration to a minimum by neutralizing the unbalanced forces of the reciprocating motion of the pistons and connecting-rods. The balancer assembly, which is shown in Fig. 10, is mounted directly below the center main bearing, and is attached to a specially shaped bearing cap *a*. The upper part of the bearing, as well as all other parts of the engine with the exception of a part of the crank-shaft *b*, have been omitted in the illustration, in order to show the construction of the balancing device more clearly.

The assembly consists of a malleable iron frame *c*, which is fastened to the bearing cap *a* by means of the bolts *d* and the castellated nuts *e*; two steel cylinder gears or drums *f* and *g*, and a bronze gear *h* with helical teeth. The gear *h* is mounted rigidly on a flange or web *i* on the crank-shaft, and is fastened by four capscrews *j* and two dowels *k*. It meshes with and

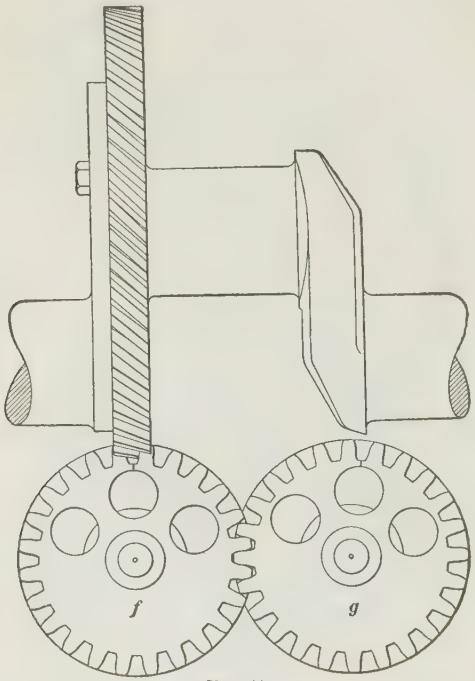


FIG. 11

drives the first drum *f*, which, in turn, drives in an opposite direction the drum *g* with which it is in mesh. The bronze ring gear *h* has twice as many teeth as the small cylinder gear *f*, and hence the latter rotates twice as fast as the larger gear, or twice crank-shaft speed. The drums or cylinder gears *f* and *g* run on hollow shafts placed at right angles to the crank-shaft, and each drum has three holes *l* drilled through it parallel to its axis. These holes are all drilled on one side of the cylinder, so that their effect is to throw the drum out

of balance, and are so located in relation to each other in the two drums, that both sets of holes are vertically up or down at the same time. Moreover, the rotations of the balancing drums are so timed in relation to the crank-shaft that the heavy sides are vertically down when the cranks are in their dead-center positions, as shown diagrammatically in Fig. 11.

The explanation of the action of the harmonic balancer in overcoming the vibrations of the engine on which it is used is too technical and difficult of understanding to be of interest to the average automobile man. It is believed, therefore, that

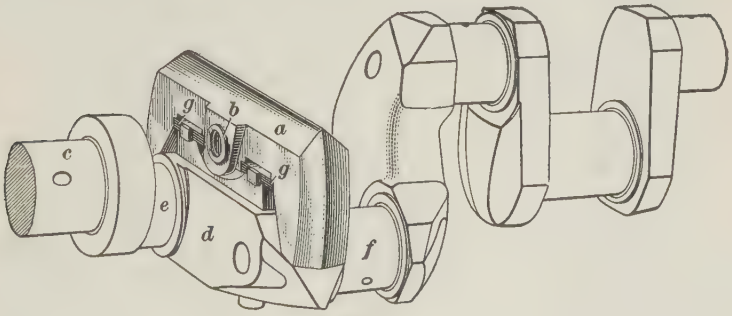


Fig. 12

the following general statement of its action will prove sufficient for the purpose.

The weighted sides of the balancer drums *f* and *g*, Figs. 10 and 11, are so located in respect to the reciprocating parts of the engine that they at all times exert a force that is directly opposite in direction to the unbalanced forces of the engine, and the weight of the heavy sides of the balancers has been so calculated by the designers of the device, that the forces set up by the rotating parts of the balancer are exactly equal to those of the engine. The two unbalanced forces thus being equal and opposite to each other are neutralized, and the result is a freedom from vibration in the engine.

The harmonic balancer can be applied to any late model four-cylinder Willys-Knights engine; it is necessary, however, to replace the crankshaft and the crank-case by others made for the purpose.

15. Oakland Harmonic Balancer.—The harmonic balancer used on late models of the Oakland engine consists of a light steel bar *a*, Fig. 12, pivoted at its center *b* to the first throw of the crank-shaft *c*, that is, to the crank-arm *d* between the crankpins *e* and *f* of cylinders No. 1 and No. 2. The tendency of the bar *a* to swing on its pivot is resisted by the flat springs *g* at each side, the weight of the bar and the stiffness of the springs being so proportioned that the balancer has a natural frequency of vibration practically the same as that of the shaft itself. When, therefore, there is the slightest movement of the shaft *c*, the harmonic balancer picks it up and vibrates in an opposite direction, so that each movement of the shaft is opposed by a heavy force that the balancer applies through its springs, and the shaft is thus held steady.

VALVE MECHANISM

16. Valves.—Valves are employed in gasoline automobile engines to control the admission of the charge and the expulsion of the burned gas, or exhaust. These valves, which are known as poppet valves, consist of a disk with a stem at right angles to the disk. They move in the direction of the axis of their stems, and are held to their seats by springs. As they open inwards, they have no tendency to leave their seats during the explosion, the pressure in the cylinder helping to keep them on their seats. The valve seats and the valve-stem guides may be located in removable heads or in the cylinder casting.

The valve seats, being directly in the cylinder or cylinder-head casting, are of cast iron. Valves are made of different materials, among which may be mentioned cast iron, tungsten steel, and various alloys such as nickel-steel, chrome-vanadium, cobalt-chrome, chrome-nickel, etc. In some cases, the valve heads and the stems are made of different materials, the valves sometimes having heads of cast iron or alloy steel, and stems of soft steel.

Valves are practically always beveled to an angle of 45 degrees, as this type of valve can be kept tight more easily than the flat-seat type that has been used to some extent.

17. Operating Mechanism.—A typical valve operating mechanism is shown in Fig. 13. The valve disk *a* rests on the beveled seat *b*, and the stem *c* extends downwards through the guide *d* to the adjusting screw *e*, which is not a part of the valve stem, however. The valve spring *f* is held in compression between the guide *d* and the cap *g*, the cap being held in place by the collar *l* with a radial slot that fits in a groove around the stem *c*. Frequently, the spring cap *g* is held in place by a pin that passes through a hole in the valve stem, instead of by a slotted collar.

The shaft *h* carries the cam *i* and as the cam turns, its lobe comes directly under the valve lifter *j*, and the valve is raised against the pressure of its spring *f*, thus forming an opening between the valve disk *a* and its seat *b*, through which the fresh charge enters the engine cylinders or the exhaust gas passes out. The valve lifter *j* is carried in a removable guide, and has at its top a locknut *k* by which the adjusting screw *e* is held firmly in place after the necessary valve adjustment has been made. The top of the valve disk is provided with a suitable slot or with depressions to receive the tool used in grinding the valve to its seat.

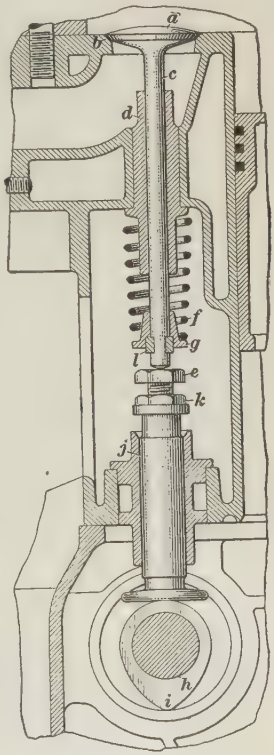


FIG. 13

18. Valve Springs.—Valve springs are usually made from steel-spring wire or from soft cast-steel wire, the former being wound cold and not requiring any heat treatment; when the soft wire is used, the spring is hardened and tempered after it is formed. Springs made from spring wire have the disadvantage of becoming set if subjected to hard usage, and

hardened and tempered springs are liable to break if not tempered just right.

19. Cams.—The cams that operate the valves of an automobile engine are usually forged in one piece with the camshaft, as shown in Fig. 14. They vary considerably in shape,

Fig. 14

or profile, the outline depending to some extent on the type of cam-follower, which is that part of the valve lifter that is in immediate contact with the cam. Examples of the different forms of cams are shown in Fig. 15.

20. Valve Lifters.—If the inlet and exhaust valves of an automobile engine are located in the sides of the cylinders, they are usually operated directly from cams acting on valve lifters, which are placed between the cams and the valve stems. There are various designs of valve lifters; some are flat where they rest on the cams, others are rounded off, and still others are provided with rollers at the bottom end. In some cases, as, for instance, in the Hupmobile eight-cylinder engine, the valve lifter is in the form of a swinging arm, the free end resting on the cam and underneath the valve stem. All valve mechanisms, with the exception of the Ford car, are provided with some means of adjusting the clearance between the valve stem and the valve lifter. This adjustment is usually placed on the upper end of the valve lifter, although in the Hupmobile eight-cylinder engine, it is placed on the lower end of the valve stem.

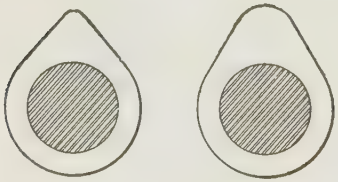


Fig. 15

Poppet valves that are located in the cylinder head and open downwards are operated by means of long rods reaching from the valve lifters to the valve rockers, or in a few rare cases,

are operated by an overhead cam-shaft. At present, the use of the overhead cam-shaft is limited largely to racing-car and aeroplane engines.

In all modern cars, even those with overhead valve engines, the entire valve gear is covered by a dust-proof, and usually an oil-proof, housing that can readily be removed.

21. Cam-Shaft Drive.—The cam-shaft of a four-cycle engine, irrespective of the number of cylinders, must be positively driven, either by gearing or by sprockets and chain, at *one-half crank-shaft speed*, in order to operate the valves properly. In many engines there are one or more other shafts that are positively driven from the crank-shaft, such shaft or shafts being used to drive a water pump, ignition apparatus, electric generator, or other parts. No definite rule applicable to all cases can be given as to the speed of such shafts in relation to the crank-shaft, as it depends on many variable factors; it is worked out by the designer for every new model of engine. The cam-shaft driving gearing is located at the forward end of the engine, and is fully enclosed by a removable cover-plate.

22. Dual Valves.—The manufacturers of some engines provide two inlet valves and two exhaust valves in each cylinder, with a view of taking in a greater charge and more completely ridding the cylinders of exhaust gases, thereby obtaining greater power and decreased fuel consumption. The same opening could be obtained by using a single valve of twice the diameter of one of the smaller ones, but valves will operate satisfactorily only up to a certain size. If this size is exceeded, the valve will warp and burn and have a consequently short life.

The area of a 3-inch circle is considerably greater than the area of two $1\frac{1}{2}$-inch circles. This can be demonstrated by placing two pasteboard disks, each $1\frac{1}{2}$ inches in diameter, side by side on a 3-inch disk, or by drawing two $1\frac{1}{2}$-inch circles in a 3-inch circle. In actual figures, the area of the 3-inch circle is double that of the two $1\frac{1}{2}$-inch circles, the area of the 3-inch circle being 7.068 square inches and the combined area of the $1\frac{1}{2}$-inch circles being 3.534 square inches. The area of the valve opening, however, does not depend upon the area of

the valve head, but upon the circumference and the lift of the valve. With a valve lift of $\frac{3}{8}$ inch, for instance, as shown in Fig. 16 (*a*), the area of the opening between the valve *a* and the valve seat *b* is equal to $3\times3.1416\times\frac{3}{8}=3.534$ square inches. Similarly, in the case of the two $1\frac{1}{2}$-inch valves shown in view (*b*), the area of the opening between the valves *a* and the seats is equal to $2\times1\frac{1}{2}\times3.1416\times\frac{3}{8}=3.534$ square inches.

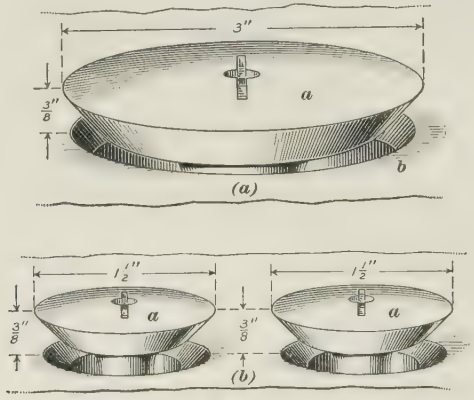


FIG. 16

The same results are therefore obtained by using two smaller valves, as by using one large valve of twice the diameter and of equal lift.

EXAMPLES OF ENGINE CONSTRUCTION

SIX-CYLINDER TYPES

23. Water-Cooled Engine. Vertical cylinder engines do not differ essentially from each other, and the description of a four-cylinder engine, given in the previous Section, will apply in general to all other vertical types of poppet-valve engines, especially of the L-head type, or those having the valves located at one side of the cylinder. The overhead valve engine, however, offers a somewhat different construction, and the following description of a six-cylinder engine of this type will serve to show the construction of practically all valve-in-the-head engines, irrespective of the number of cylinders.

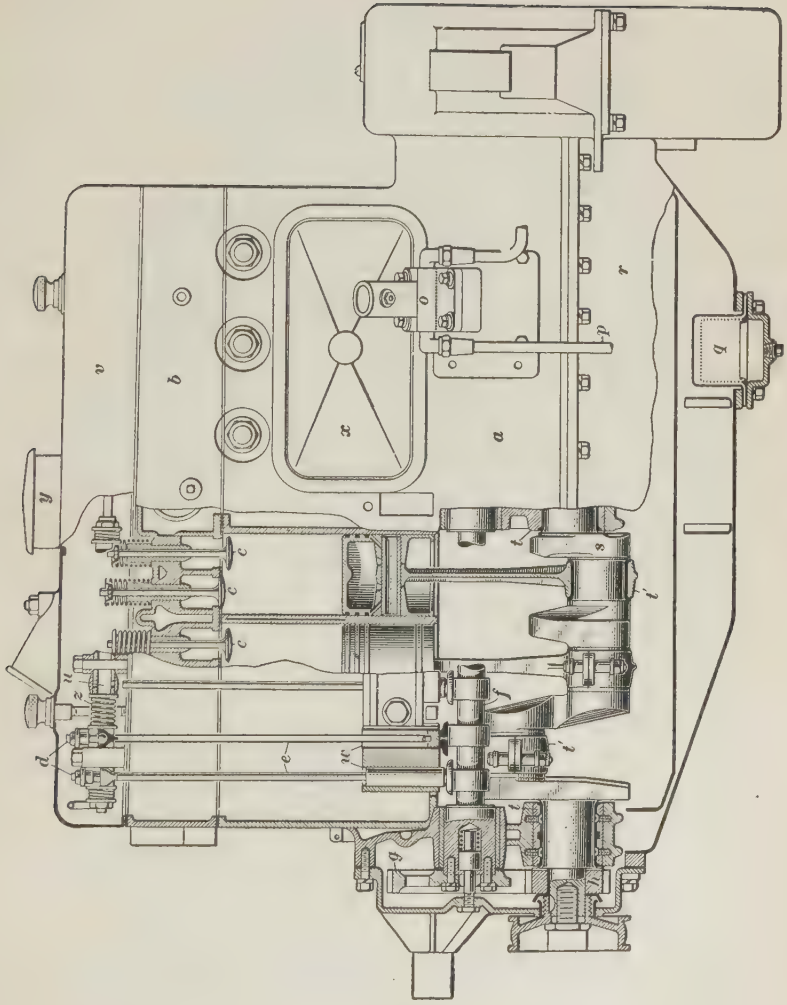


FIG. 17

In Fig. 17 is shown a part-sectional view of the left side of a six-cylinder overhead valve engine, with the clutch, transmission, etc., omitted, and in Fig. 18 is shown a cross-section through one of the cylinders, as viewed from the front of the engine. As far as possible, the same parts have been lettered alike in the two illustrations, and both should be referred to in reading the description.

The six cylinders and the upper crank-case *a* are cast in block, a detachable cylinder head *b* being used, in which are carried the inverted overhead valves *c*. These valves are operated by valve rockers *d* and push rods *e* from the cam-shaft *f*, this shaft being driven from the crank-shaft at one-half crank-shaft speed, by helical-tooth gears *g* and *h*. The shaft *i* of the timer-distributer *j* of the ignition system is driven from the cam-shaft by the helical gears *k* and *l*. The shaft *i* also drives the spur gears *m* and *n* of the oil pump *o*, gear *n* being mounted on the shaft. The oil pump is connected by the pipe *p* to the oil screen *q*, located at the lowest point of the oil pump in the crank-case *r*. Oil is pumped directly into the hollow crank-shafts *s* and to the different main bearings *t*, and the connecting-rod bearings *t'*. From the main bearings the oil is forced through drilled passages to the cam-shaft bearings. The overhead valve mechanism is also lubricated by pressure, the oil passing through a pipe to the hollow rocker-arm tube *u*, and thence to the different bearings and operating mechanism. The valves and valve rockers are enclosed in a metal cap *v*, and the push rods *e* and the valve lifters *w* are in a space closed by removable cover-plates *x*. The oil filler is located at *y* in the cover-plate. Small compression springs *z* are placed against the valve rockers *d* in order to quiet their action as their bearings become worn.

At *a'* is shown the flange against which the electric starting motor is bolted. The starter, which is not shown, is used to crank the engine until it starts to run under its own power.

24. Air-Cooled Engine.—The Franklin air-cooled engine, a cylinder of which was shown in *Gasoline Automobile Engines*, Part 1, has many individual points of design, but as a whole,

follows the same general method of construction and operation as other automobile engines. Its main point of distinction, however, is in the use of air for cooling purposes, instead of

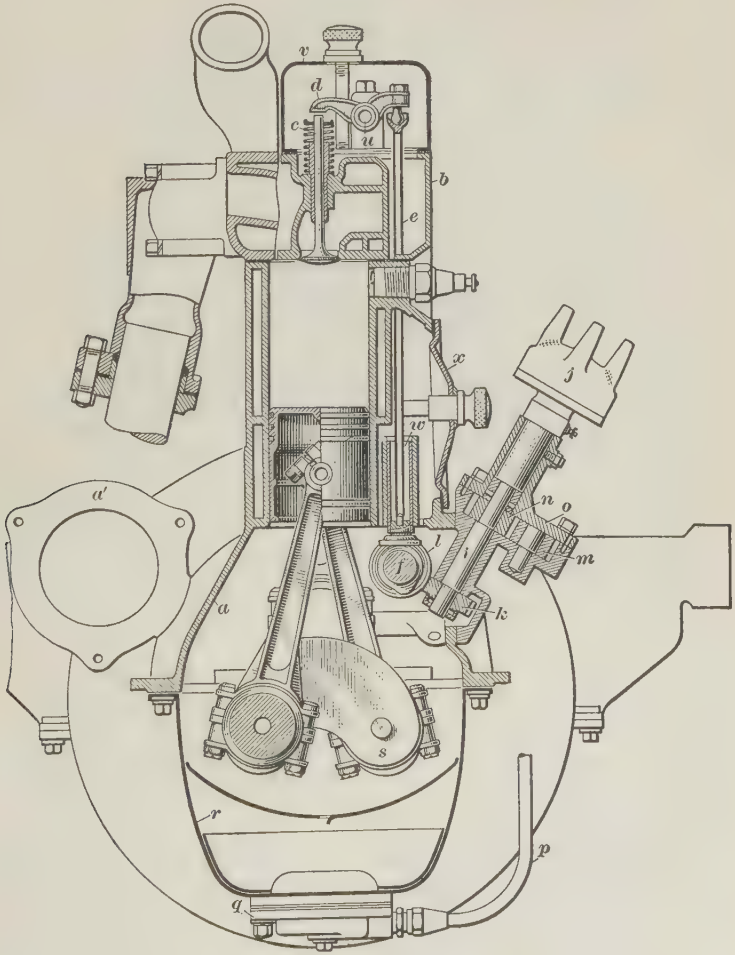


FIG. 18

water. The method of forcing the air past the cylinders in sufficient volume to carry off the heat from the cylinders is shown in Fig. 19, some of the housing of the cooling system

being cut away so as to show the interior. The cooling system consists of the housing *a* at the front of the engine, the housing *b*, covering the tops of the cylinders, the blower *c*, and the steel flanges *d* around the cylinders *e*. The air is taken in at the opening *f* at the front of the housing *a* and is forced in large volume by the blower *c* into the upper housing *b*, thence past the outer walls of the cylinders through the channels formed by the flanges *d*. The steel flanges carry the heat from

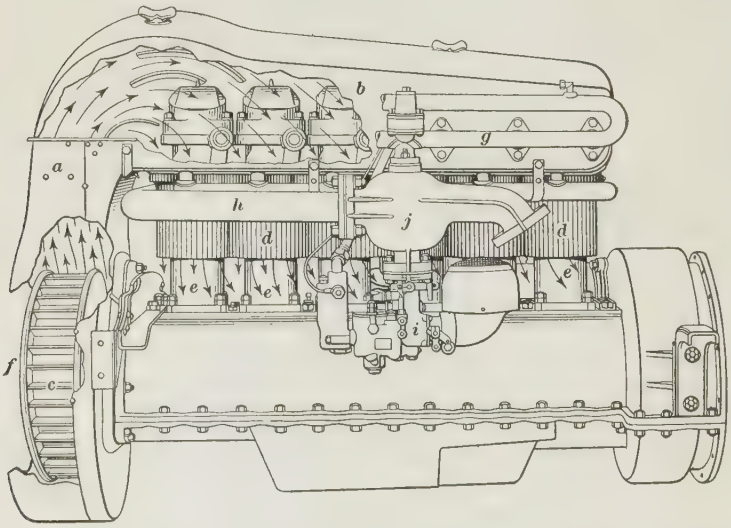


Fig. 19

the cylinder walls, and the direct application of the air-currents to each cylinder carries the heat from the flanges. The course of the air through the cooling system of the engine is indicated by the arrows in the illustration.

The blower *c*, which is mounted on the forward end of the crank-shaft, is constructed with a large number of narrow vanes at its periphery, and this construction together with the new design of the combined housing *a b* gives an air capacity greatly in excess of the flywheel fan system employed in earlier models of the Franklin engine.

In Fig. 19, the inlet manifold is shown at *g*, the exhaust manifold at *h*, and the carbureter at *i*. The enlarged section *j*

of the exhaust manifold forms a gas heater in which any unvaporized gas that leaves the carbureter is vaporized before it reaches the inlet manifold *h*.

EIGHT-CYLINDER ENGINES

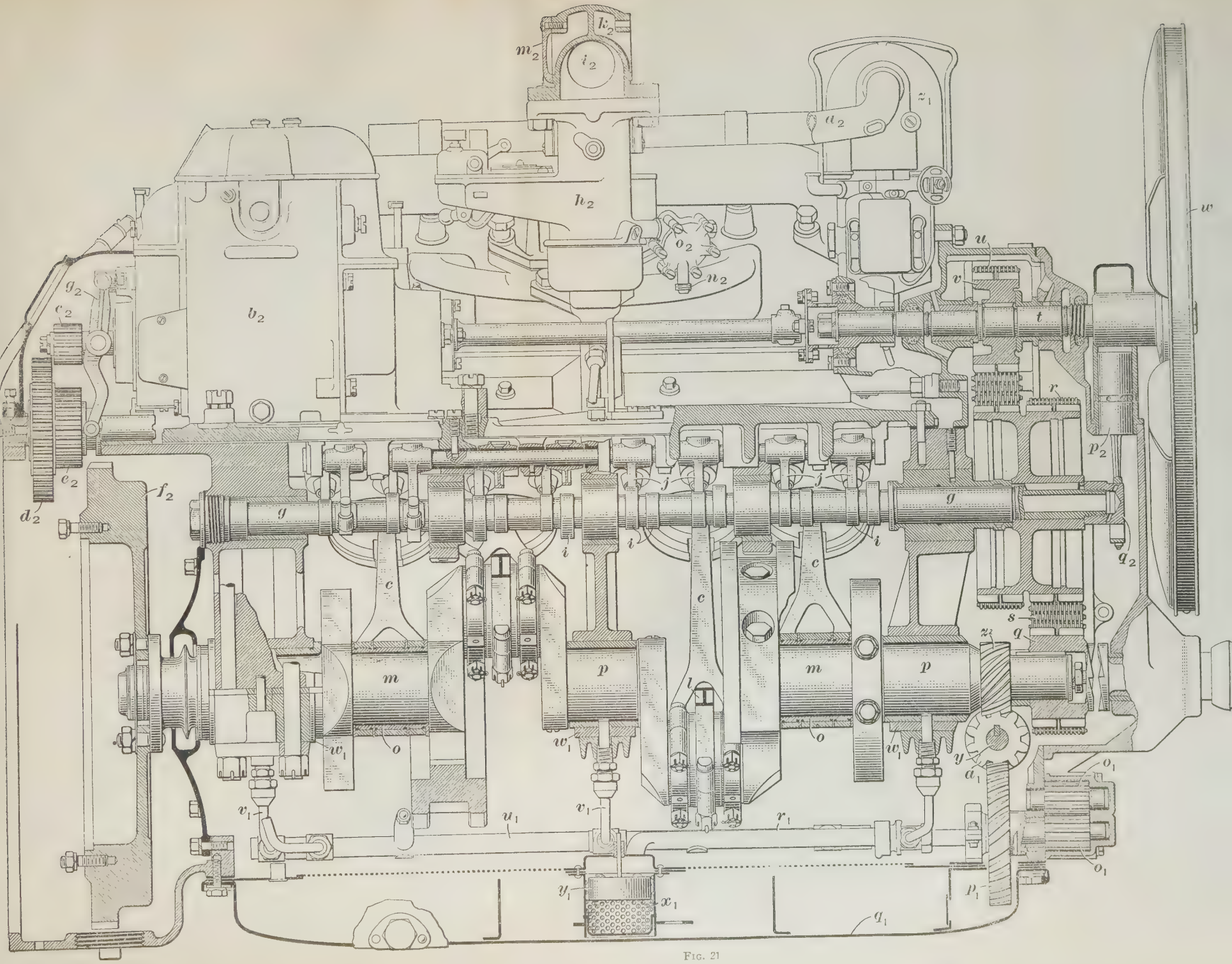
25. V-Type Engines.—The arrangement of the parts of a typical 8-cylinder **V**-type engine is shown in Figs. 20 and 21, Fig. 20 being a part sectional front view, and Fig. 21, a part sectional side view of the Cadillac engine. The same reference letters are used on the same parts that appear in both illustrations. The cylinder blocks *a* and *b*, Fig. 20, are set at an angle of 45° from the vertical, or 90° from each other. The general construction of the cylinders, the removable cylinder head, the valve mechanism, etc., follows conventional design, as already described, and will not be taken up again in detail. The connecting-rod *c* is shown as though broken off near the piston *d*, and the piston is turned 90° from its working position, so as to show the mounting of the wristpin *e*, which is fastened by the pin *f*. The single cam-shaft *g* operates all of the valves *h* of both blocks of cylinders by means of sixteen cams *i* and a similar number of rocker-arms *j*, the rollers *k* of the rocker-arms being in contact with the cams at all times. The two connecting-rods that are mounted on a single crankpin are shown at *c* and *l*, the rod *c* being mounted directly on the pin *m*, and the other connecting-rod *l* on the bushing *o* of the rod *c*. The cam-shaft *g* is driven from the crank-shaft *p* by means of the 2 to 1 sprocket gears *q* and *r*, Fig. 21, the gear *q* driving the double gear *r* through the silent chain *s*. The rear portion of the gear *r* drives the overhead shaft *t* by means of the silent chain *u* and the sprocket gear *v*. The shaft *t* drives the fan *w* and the electrical apparatus. The method of driving the various shafts by means of chains and sprockets is known as a front-end chain drive.

26. There are two centrifugal water pumps *x*, Fig. 20, one for each cylinder block, which are driven by the transverse shaft *y*, which, in turn, is driven by the helical gears *z* and a_1

from the crank-shaft. Carried on the outer cover-plate of each pump housing is a thermostat b_1, the purpose of which is to divert the main flow of water in the cooling system away from the radiator until the temperature is raised to the desired point. When the engine is cool, as when starting, or when running in very cold weather, the water circulates through the pump at each side, through the hose connection c_1 to the cylinder water-jacket d_1, thence to the cylinder-head jacket e_1, the by-pass f_1, the thermostat b_1, and back to the pump. When the engine warms up to the desired temperature, each of the pump inlets g_1 that are connected to the sides of the radiator, is opened by the thermostat, and the inlet leading to the pump from the by-pass f_1 will be nearly closed. The main body of water in the cooling system will then flow from the pump to the cylinder jackets through the pipe c_1, thence through the upper radiator connection h_1, the radiator, not shown, the lower connection g_1, and back to the pump, until the temperature of the engine, and therefore the water, once more falls below the desired working point. The packing gland that prevents leakage from the water pump is shown at i_1, and its adjusting nut at j_1. The nut j_1 is made accessible by means of the opening k_1 in the extension of the pump housing. The packing gland that prevents leakage of oil from the crank-case past the shaft y is shown at l_1 and its adjusting nut at m_1. The outer bearings of the shaft y are lubricated by a grease gun fitting on the tube n_1.

27. The gear oil pump o_1, Figs. 20 and 21, is driven by the helical gear p_1, which meshes with the gear a_1 on the pump shaft. The pump draws its oil supply from the central and deepest compartment of the oil pan q_1 through the pipe r_1 and the manifold s_1. From the pump, the oil is conveyed through the manifold t_1 to a pipe u_1 that runs the length of the crank-case. Leads v_1 connect this pipe with the main bearings w_1 of the engine. The oil strainer is shown at x_1, and the float of the oil gauge at y_1.

The ignition timer-distributer z_1 is mounted at the top of the engine and between the two cylinder blocks. The high-


k_2
m_2
i_2
z_1
a_2
h_2
w
o_2
n_2
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v
t
g_2
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p_2
e_2
f_2
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FIG. 21

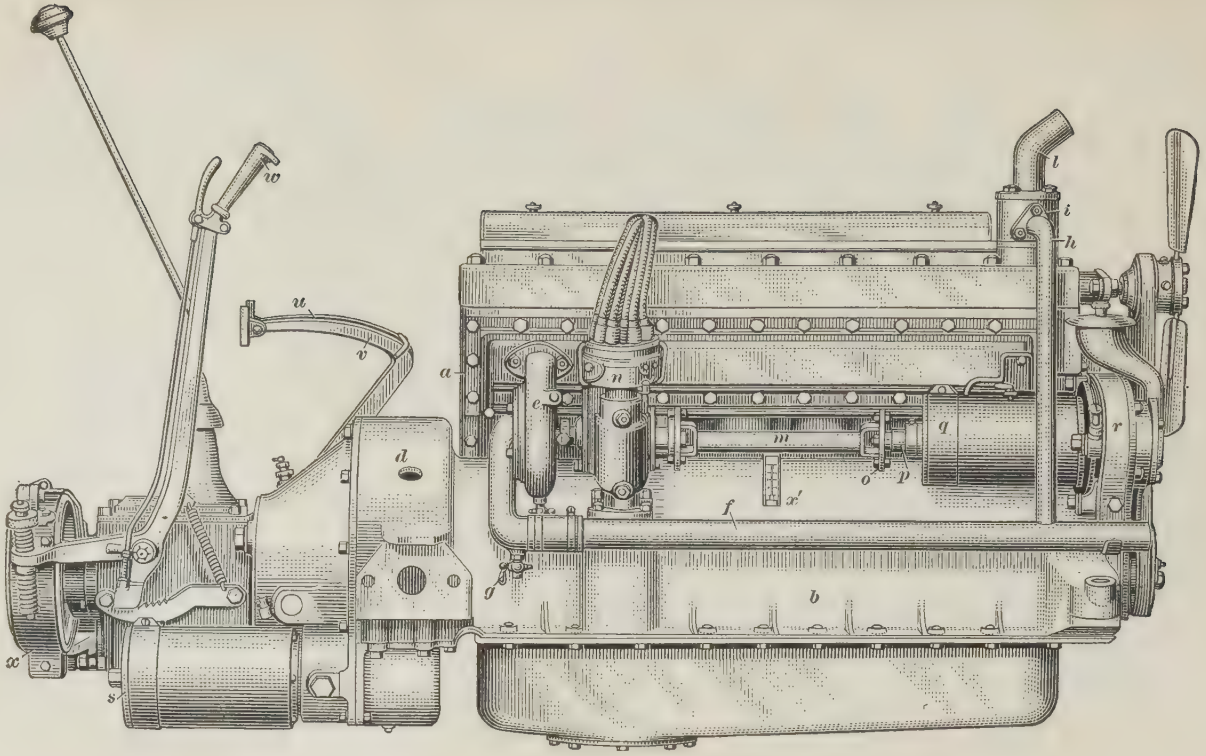


FIG. 22

tension ignition cables are enclosed except at their ends in the conduits a_2. The machine that is utilized for starting the engine, and as the source of current for lighting and ignition purposes when the engine is running, is shown at b_2, and is known as a starter-generator. In starting the engine the gear c_2 meshes with the gear d_2; and the gear e_2, which is in one piece with gear d_2, is in mesh with the flywheel gear f_2. The gears d_2 and e_2 are shifted into mesh with the gears c_2 and f_2 by foot through a pedal, not shown, and the lever g_2.

The carbureter h_2 is also located on the top of the crank-case and between the two cylinder blocks. The intake header i_2 is connected by the manifolds j_2 to the intake ports of the cylinders. A passageway k_2, which connects the two exhaust manifolds l_2, and which is normally closed by the plate m_2 on each side, encloses the inlet header i_2, the hot exhaust gases thus being utilized to heat the fuel mixture as it leaves the carbureter, and so insuring good carburetion at all times. Individual mufflers, not shown, are employed with the two exhaust outlets. The gasoline pipe connection to the carbureter is shown at n_2, and the gasoline strainer at o_2.

The air-pump, or compressor, that forces air into the gasoline tank, is shown at p_2. By means of this pump, which is driven by an eccentric q_2 on the cam-shaft g, a positive feed of fuel from the main tank to the carbureter is assured.

28. Vertical-Eight Engines.—Straight-eight or vertical-eight engines do not differ radically from other water-cooled poppet-valve engines, and the following descriptions of representative types will serve to show the general features of design of engines belonging to this class.

In Figs. 22, 23, and 24 are shown an outside view of the right-hand side, and a part sectional view of the left-hand side, and a section through one of the cylinders, respectively, of the Hupmobile eight-cylinder engine. This engine is an excellent example of the small, compact type of multiple-cylinder engine that is becoming prevalent in later-day automobile construction, the overall length being very little more than that of the average six-cylinder engine. In reading

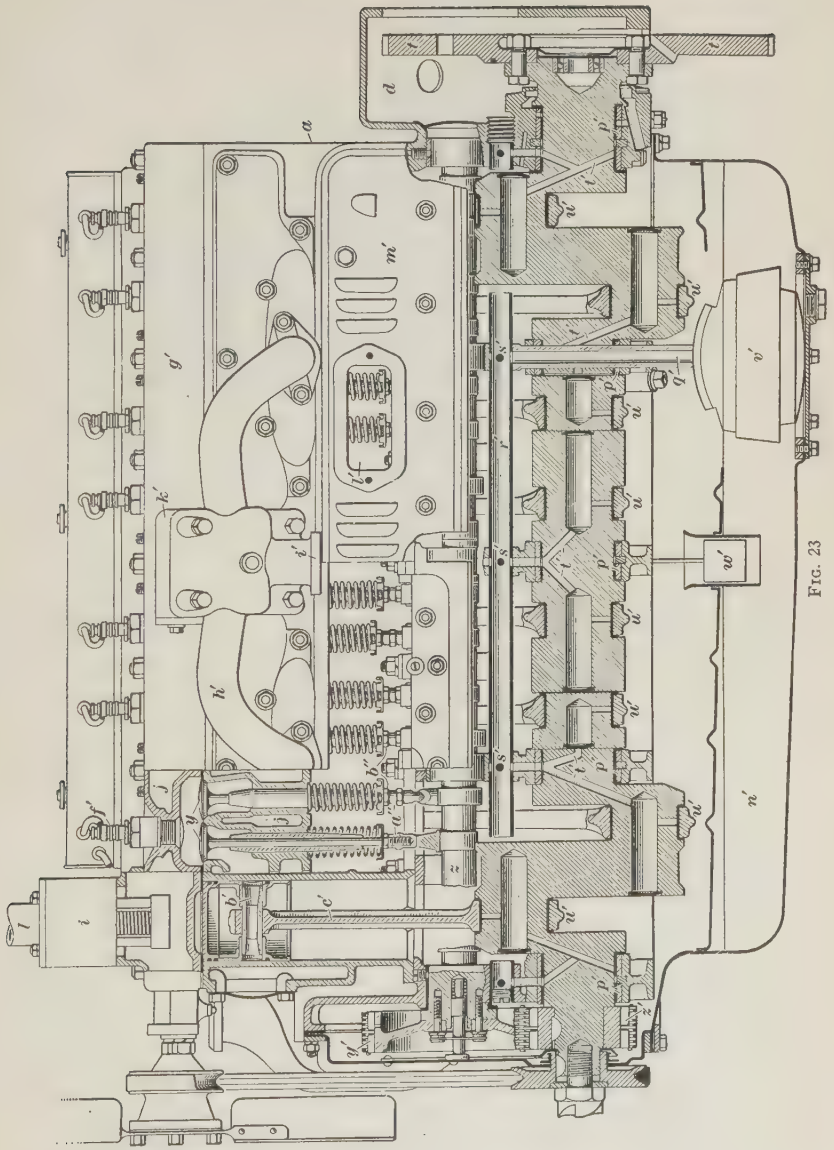


FIG. 23

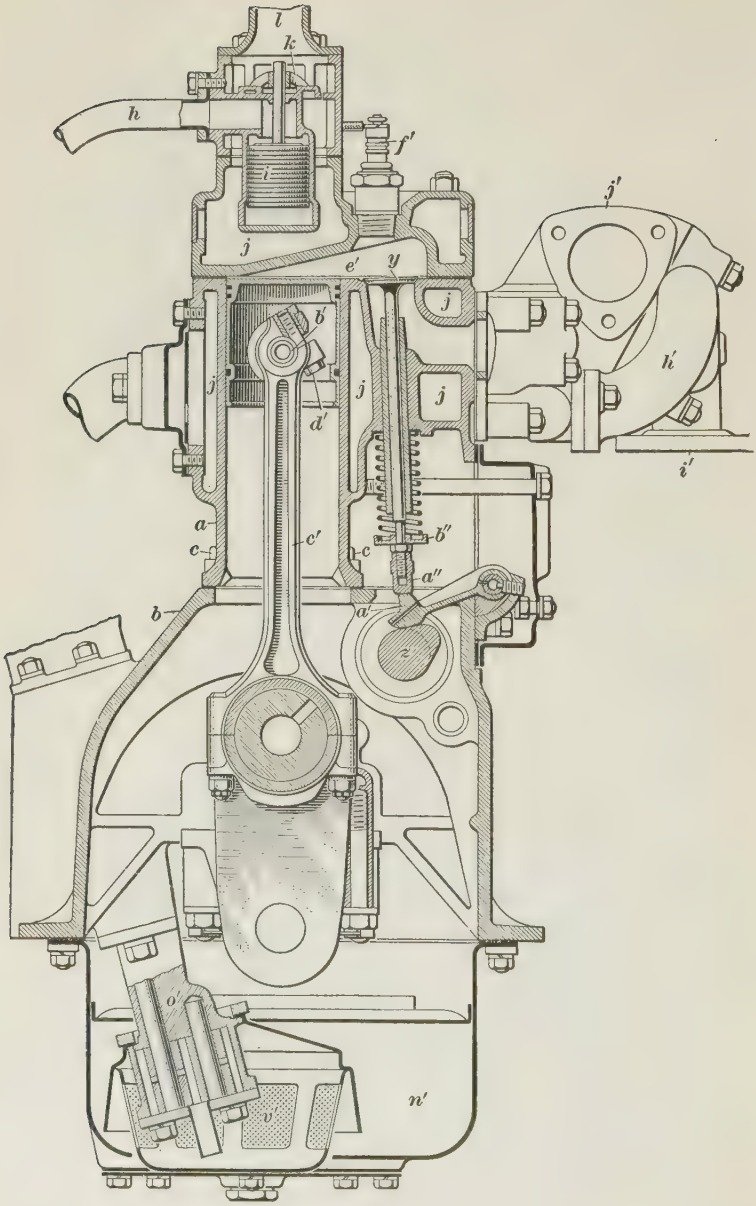


Fig. 24

the description, all three illustrations should be referred to, as the same parts are lettered alike as far as possible in the different views.

The cylinders *a* are cast in one block, but are separate from the upper crank-case *b*, being fastened to it by the studs and nuts *c*. The upper crank-case is cast in one piece with the upper flywheel housing *d*. The water pump *e* is located at the end of the engine away from the radiator, instead of at the end nearest to it, as is the usual construction. A long pipe *f* connects the inlet of the pump to the radiator. The drain cock *g* on the water inlet elbow is the lowest point in the cooling system, and makes possible the draining of all of the water from the system. A by-pass *h* joins the main water pipe *f* and a thermostat *i*, and when the engine is cold the water circulates through the by-pass *h*, the pipe *f*, the pump *e*, the cylinder and cylinder-head jackets *j*, and back to the thermostat. When the water becomes heated, the thermostat valve *k* opens the passage leading to the water outlet *l* that connects with the top of the radiator, and the water then circulates through the cylinder jackets and the radiator. The water pump is driven by the shaft *m*, which also drives the timer-distributer *n*. This shaft is driven through the coupling *o* by the armature shaft *p* of the generator *q*. The generator, which is bolted to the crank-case flange *r*, supplies current for the lights and the ignition when the engine is running.

29. The starting motor *s*, Fig. 22, is bolted to the clutch housing, and a gear on its armature meshes with gear-teeth on the flywheel *t*, Fig. 23, when the starting pedal is pressed down. The engine is then turned over by the storage battery. The pedals *u* and *v*, Fig. 22, operate the clutch and the four-wheel service brakes, respectively, while the hand lever or emergency lever *w* operates a brake *x* on the transmission shaft. This type of brake is known as the transmission brake, and is now being used quite extensively.

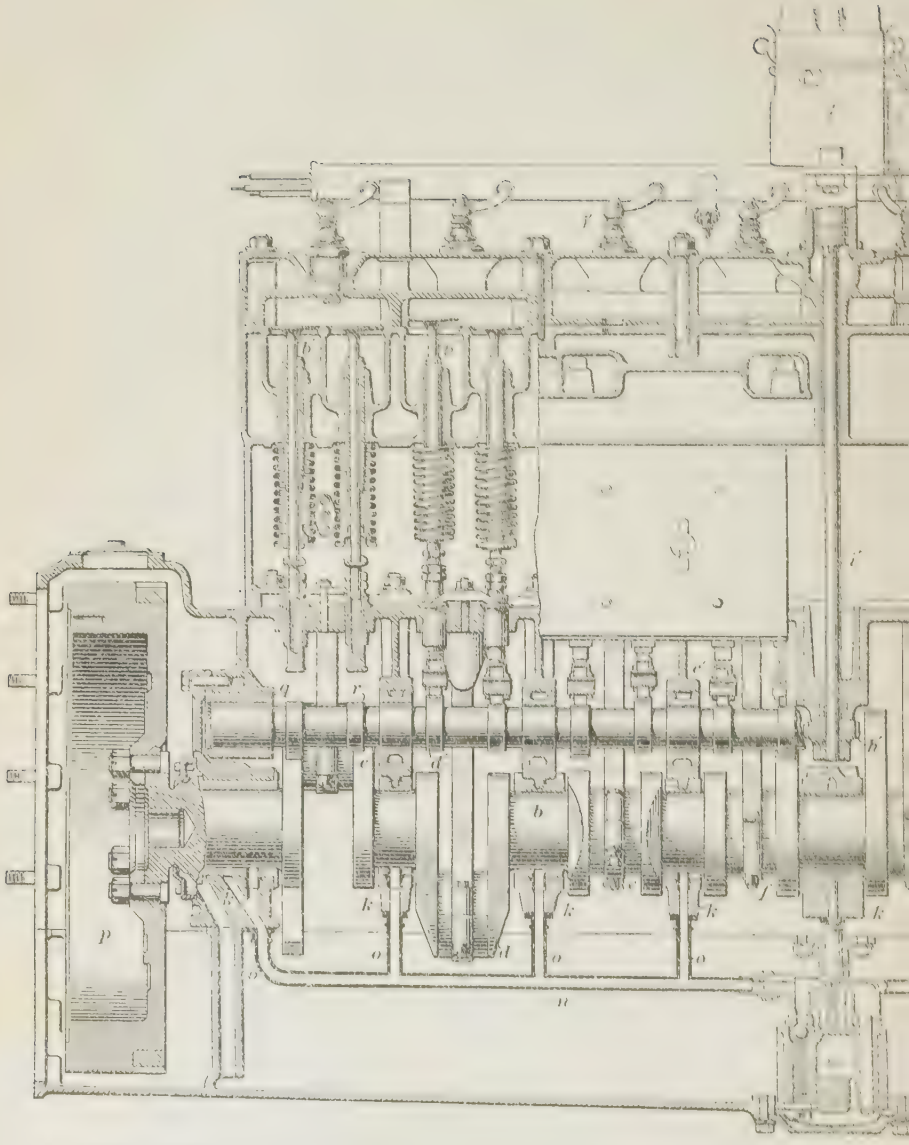
The engine is of the L-head type, the two valves *y*, Figs. 23 and 24, of each cylinder being operated from the cam-shaft *z* by the rocker arms *a'*. Rocker,arms of the type shown are

known as cam-rockers, as they rest directly on the cams. The wristpin b' is fastened in the upper end of the connecting-rod c' by means of the lock bolt d', and has its bearings in the piston. The combustion chamber c' is of the modified Ricardo type, being of much less volume over the piston than over the valves y. The spark plug f' is placed so as to fire into the pocket directly over the valves. The exhaust manifold is shown at g', and the inlet manifold at h', the flange by which the carbureter is connected to the manifold being shown at i'. The exhaust pipe that connects the exhaust manifold to the muffler fastens to the flange j'. A stove k', which is around the header of the inlet manifold, and through which the exhaust gas passes, heats the fuel mixture on its way to the engine cylinders. The firing order of the engine, which is 1–5–2–3–8–4–7–6, is cast on the cover of the stove k'. The air inlet to the carbureter is connected to the opening l' in the valve cover-plate m', hot air thus being drawn into the carbureter intake from around the engine cylinders.

30. The engine is lubricated by the pressure system, the oil supply, which is, as usual, carried in the oil sump n', Figs. 23 and 24, of the lower crank-case, being forced by the gear-pump o' into the five crank-shaft bearings p' through the passage q', the tube r' that runs the length of the crank-case, and the lead s' to each crank-shaft bearing. The oil is then forced from these bearings through the openings t' in the crank-shaft to the connecting-rod bearings u'. Leads from the main oil pipe r' supply oil to the cam-shaft bearings. The piston and cylinder walls are oiled by spray from the connecting-rod bearings. The oil strainer is shown at v', the float for the oil gauge at w', and the gauge at x', Fig. 22.

The cam-shaft sprocket y', Fig. 23, is driven at one-half crank-shaft speed by means of the crank-shaft sprocket z' and a silent chain.

The valve adjustment on the Hupmobile is peculiar in that the adjusting nut a'' and the locknut b'', Fig. 24, are located on the end of the valve stem, rather than on a separate lifter, as is the usual construction.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b'
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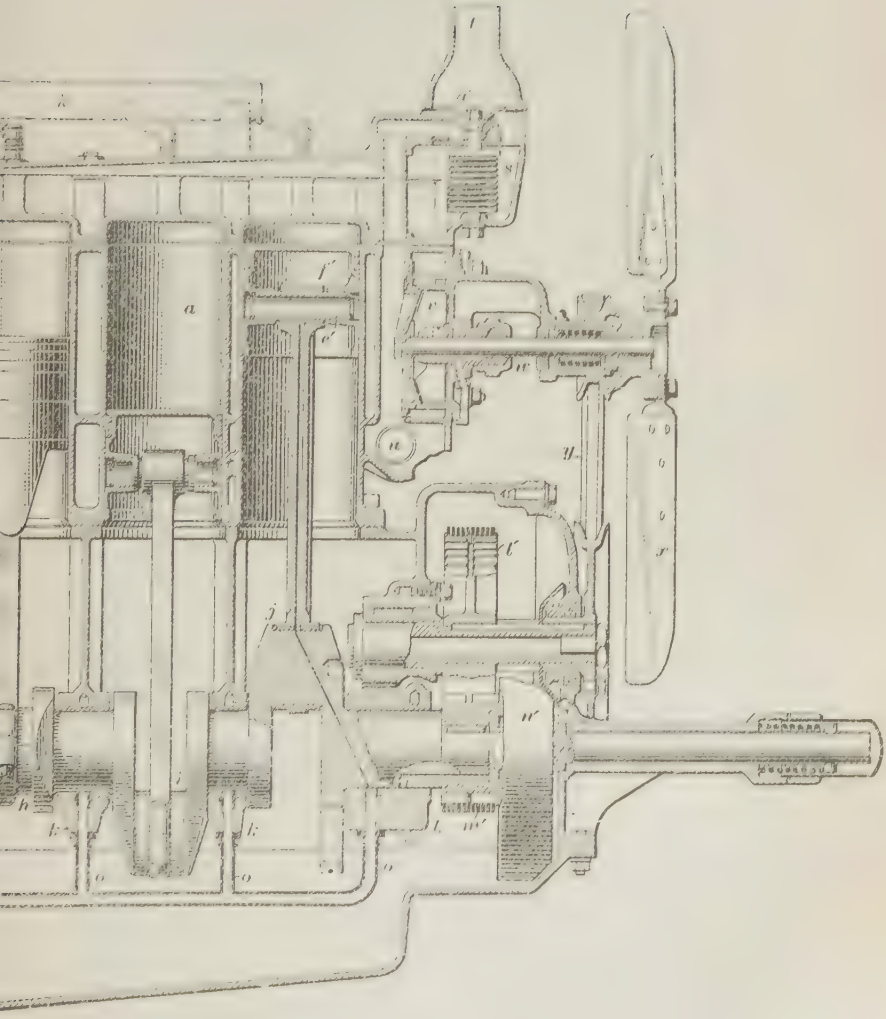


31. A part sectional view of the right-hand side of the Packard eight-cylinder engine is shown in Fig. 25. As is the case with other vertical engines, the cylinders *a* are all in a single straight line, and their connecting-rods are connected to a single crank-shaft *b*. The cranks are arranged as shown diagrammatically in *Gasoline Automobile Engines,* Part 1, cranks *c d* being 180° apart, *d e* 90° apart, *e f* 180° apart, *f g* in line, *g h* 180° apart, *h i* 90° apart, and *i j* 180° apart. The crank-shaft *b* has nine bearings *k*. The oil pump *l* forces the oil from the oil sump *m* through the main pipe *n* and the lead tubes *o* to the main bearings. The oil passes from the bearing nearest to the flywheel *p* to the cam-shaft bearing *q*, whence it passes through the hollow cam-shaft *r* to the remaining cam-shaft bearings.

32. The engine is equipped with a thermostat *s*, Fig. 25. The water outlet from the thermostat to the upper radiator connection is shown at *t* and the inlet from the radiator at *u*. The water pump *v* is mounted on the fan shaft *w* and rotates with the fan *x*, being driven by the fan belt *y*. A drilled by-pass *z* connects the thermostat *s* with the inlet side of the pump, and when the engine is cold, the opening to the passage *z* is uncovered, and that leading to the water outlet *t* is closed. The water then circulates from the pump *v* through the by-pass *z* and back to the pump. When the water heats up to the desired temperature, the valve *a'* opens the passage leading to the outlet *t*, and the by-pass is closed. Water will then circulate through the cylinder and cylinder-head jackets, and the radiator.

The valves *b'* are operated by means of rocker-arms, shown in section at *c'*, that rest on the cams *d'* of the cam-shaft. The piston pins *e'* are floating, that is, they are fastened neither to the piston nor the connecting-rod, and are prevented from moving endwise by means of the locking rings *f'* at each end.

The timer-distributer *g'* is driven from the cam-shaft *r* by means of helical gears, one of which is shown in section at *h'*, and the vertical shaft *i'*. The wires leading to the spark plugs *j'* are carried in the conduit *k'*.

The cam-shaft sprocket *l'* is driven by the crank-shaft sprocket *m'* by means of a silent chain. As stated before, the cam-shaft rotates one-half as fast as the crank-shaft, regardless of the number of cylinders in the engine. The front flywheel forming the vibration damper is shown at *n'*. This device is shown in detail in Fig. 9.

The Packard engine employs a device that cleans the oil, and the pistons *o'* are provided with extensions *p'*, the purpose of which is to keep a hole in the side of the cylinders covered when the piston is at the upper end of its stroke. The hole in the cylinder wall connects with the oil-cleaning device.

SLEEVE-VALVE ENGINES

33. General Faults of Poppet-Valve Engines.—The common type of four-cycle, poppet-valve automobile engine possesses some inherent faults that have led to the design and adoption of engines without poppet valves, such engines being intended either to better the undesirable features or to eliminate them. Many of these so-called non-poppet-valve engines have been a success from the engineering standpoint, but have not met with commercial recognition; a few have stood the test of time, are unqualified successes from both the engineering and the commercial points of view, and are used in practice. The most widely used non-poppet-valve engine is that known as the *Knight sleeve-valve engine,* and also the *Silent Knight engine.*

The faults that are inherent in the poppet-valve type of gasoline engine are: (1) Comparative absence of silence in the valve motion at high engine speeds; (2) restricted area of valve opening and winding gas passages, which cause abrupt changes in the direction of flow of the gases; and (3) undue falling off of the horsepower at high engine speeds.

34. Detailed Explanation of Faults.—The comparatively noisy action of a poppet valve is due partly to lost motion, which is due to the clearance between the valve itself and the valve-lifting mechanism, and the subsequent shock that must result when the valve begins to lift against the resistance of

the necessarily strong valve spring, and partly to the sudden seating of the valve under the influence of the valve spring. Great progress has lately been made in reducing the noisy action of poppet valves, partly by reducing the lost motion, partly by changing the outline of the cams governing the opening and closing of the valves so as to insure a gentler opening and seating of the valves, and partly by fully enclosing the valve mechanism. However, reduction of the noise in the valve action as brought about by changes in the outlines of the cam is accompanied by a still further restriction of the valve-opening area; by enclosing the valve mechanism, the noise is muffled rather than eliminated.

35. Before taking up the fault of a restricted area of valve opening, it is advisable to consider the area of valve opening produced by the ideal valve gear. Such a gear is one that instantaneously opens a valve to its full extent, holds it wide open the proper interval of time, and instantaneously closes it, thereby giving the greatest area of opening that is possible, with a valve of a given size and lift, for the admission of the fresh charge or the expulsion of the burnt gases. In designing the valve gear, it is the aim to approach the action of the ideal one as near as is practicable so as to obtain the greatest possible power from the given cylinder diameter and stroke.

The action of cams on poppet valves, even under the best of conditions, is very far from ideal, however. The valves open very gradually and close gradually, thereby greatly restricting the openings for admission and exhaust, and thus preventing the engine from attaining the power obtainable from it under ideal conditions. Any attempt to give a quick opening and closing of the valves by suitable cam outlines, so as to produce a better gas admission and freer exhaust, is attended by a very great increase in the noise of the valve action, which becomes disagreeably noticeable at high engine speeds. Consequently, in designing a poppet-valve motor, choice must be made between cam outlines producing comparative quietness accompanied by a restricted area of valve opening, and cam outlines producing comparative noise accompanied by a better valve-opening area.

36. In regard to the matter of gas passages it is obvious that the shorter they are and the freer they are from abrupt changes in direction, the less will be the frictional resistances that tend to impede the flow of gases, and, consequently, all other conditions being equal, the greater will be the quantity of gas that can flow through them in a given time. With poppet valves, no matter how short and straight the passages leading to and from the valves may be, there are abrupt changes of direction in the flow of the gas past the opened valve that retard the flow, as is indicated by the arrows in Fig. 26, which shows an open exhaust valve. This retardation of the gas is inseparable from the employment of poppet valves and prevents an engine from developing the power that could be developed if a freer flow of gas could be induced.

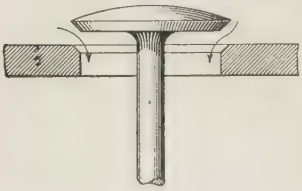


FIG. 26

37. In considering the falling off in power at high engine speeds, it must be borne in mind that both the inlet valves and the exhaust valves of the conventional four-stroke cycle engine are not closed by positive mechanical means, but by springs. These springs, no matter how stiff they are made, require an appreciable amount of time to return the valves; that is, to close them. When the engine speed becomes so high that the cam-shaft revolves faster than the springs can return the valves, the inlet valves will remain off their seats much longer than they should; hence, the compression is reduced, and this in turn reduces the pressure developed on the explosion stroke. The exhaust valves also will remain off their seats longer than they should, so that, at the beginning of the suction stroke, some of the exhaust is drawn back into the cylinder; and, as the inlet valve is open at the same time, the incoming fresh charge is diluted by the exhaust gases and thereby weakened. The combination of the weakened charge with an unduly weak compression means a greatly reduced explosion pressure, and hence a falling off in the power developed, until, finally, a point is

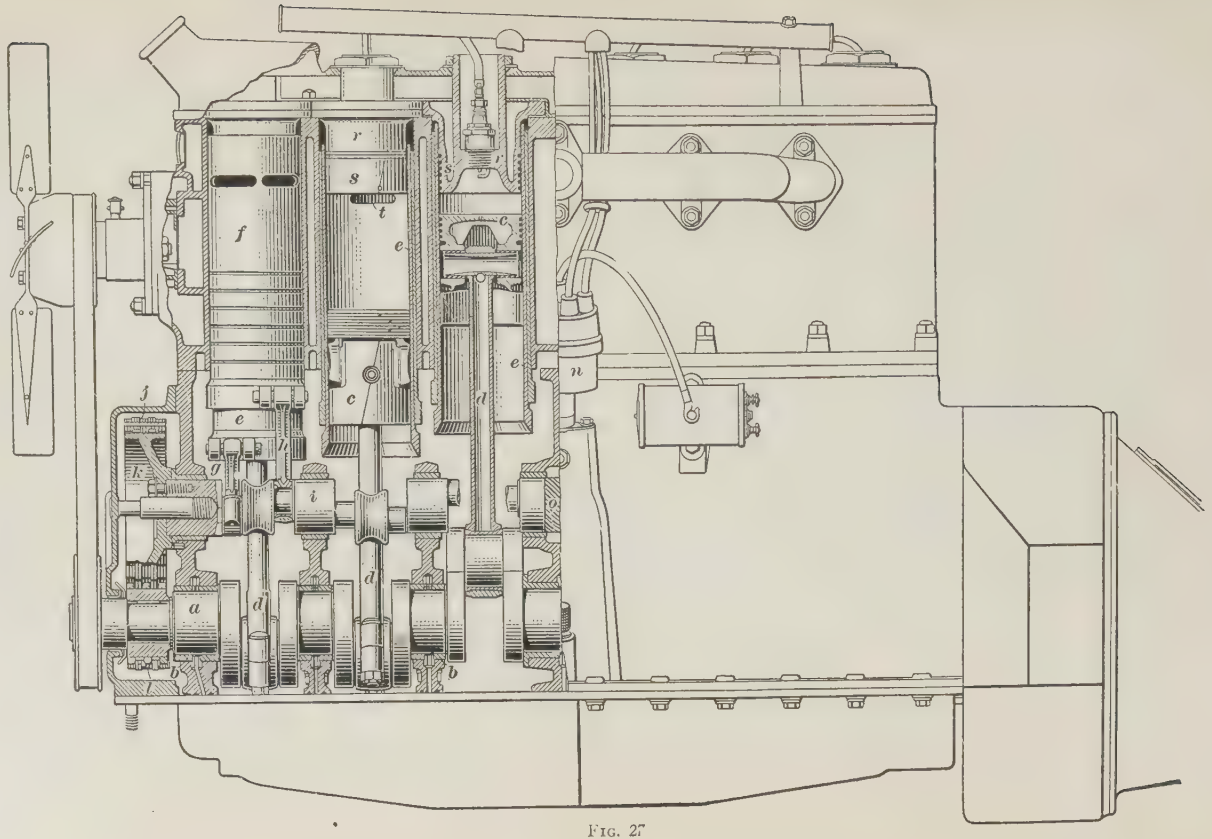


Fig. 27

reached where the horsepower not only fails to increase as the speed increases, but may actually become less than at lower engine speeds.

38. Knight Engine.—Of the different types of non-poppet valve engines that have been placed on the market, the Knight engine is the one best known and that has come into more common use. The Knight engines, built by the different manufacturers licensed to use them, and also those built at different times by the same manufacturer, naturally differ slightly in details of construction, although the principles of operation are the same in all of them. The constructions shown here and the explanations of the principles may be considered, therefore, as typical of Knight engines in general.

In Fig. 27 is shown a side view of a six-cylinder Willys-Knight engine, built by the Willys-Overland Company, a part of the engine being cut away so as to disclose the construction of the interior mechanism. This engine follows conventional construction to the extent of having a carbureter, ignition apparatus, starter, water-cooling system, etc., and it will not be necessary to refer to these details in connection with the explanation of the Knight principle, as typified by the engine shown. An end section of the engine is shown in Fig. 28, and in Fig. 29 is shown a separate view of three of the sleeves, and their actuating mechanism. As far as is practicable, the same reference letters are applied to the same parts in Figs. 27, 28, and 29, and the three illustrations should be referred to in reading the description of the engine.

39. The Willys-Knight six-cylinder engine has a crankshaft *a* supported in seven plain main bearings *b*, to which are connected six pistons *c* by the usual form of connecting-rod *d*. These pistons, however, do not work directly inside the cylinders, but slide on the inside of what are called the inside sleeves *e*. These concentric and very thin sleeves slide on the inside of the thin concentric outer sleeves *f*, the outside of which is a sliding fit in the cylinder bore. The sleeves, each of which has a stroke of 1 inch, are moved up and down in the cylinders by connecting-rods *g* and *h* coupled to the crank-

pins of a small crank-shaft *i*, which, by the builders of the engine, is called the *eccentric shaft*. Each sleeve is coupled

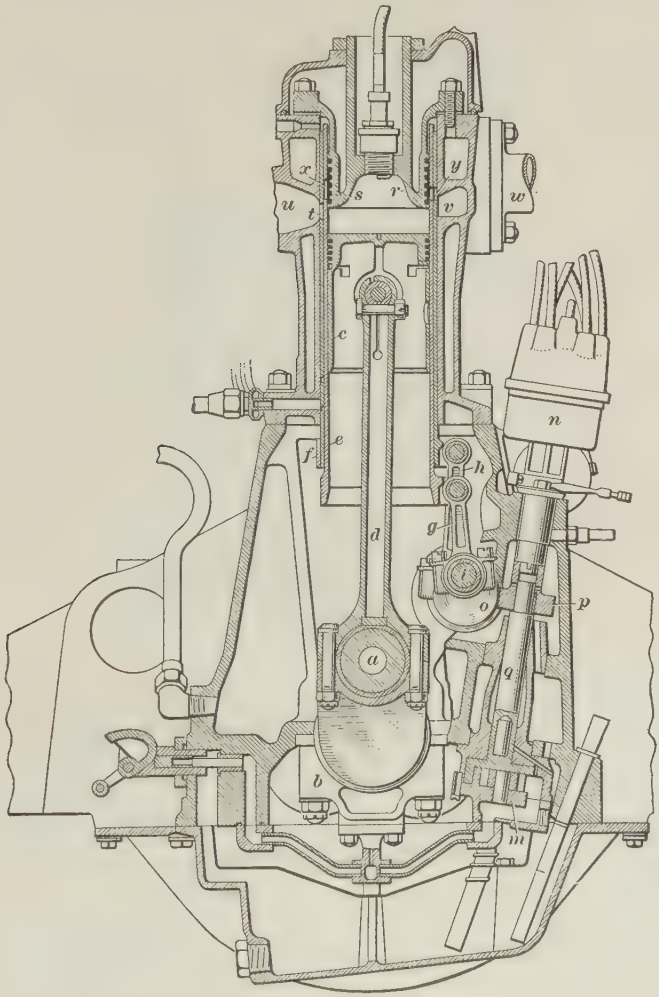


FIG. 28

to its own crankpin on the eccentric shaft, there being twelve sleeves and twelve eccentric-shaft crankpins in the six-cylinder engine. The eccentric shaft is driven at one-half the

speed of the crank-shaft and in the same direction by the silent chain *j*, which engages the sprocket wheels *k* and *l* fastened to the crank-shaft and the eccentric shaft, respectively. The oil pump *m* and the ignition timer-distributer *n* are driven from the crank-shaft by the helical gears *o* and *p*, and the shaft *q*. The inner and the outer sleeves extend far beyond the top of the piston when it is at the upper end of its stroke. The

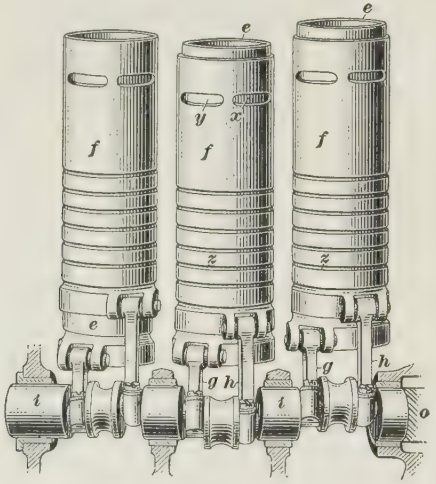


Fig. 29

cylinder-heads *r* are rather deep and carry near their lower end a broad packing ring *s*, which is known as the *sealing ring*, and which, in conjunction with a narrow packing ring, serves to make a gas-tight joint between the cylinder head and the inner sleeve. The cylinder heads, as an examination of Fig. 28 will show, are thoroughly water-jacketed; each cylinder has its own removable head.

A port *t* for the admission of the fresh charge is formed at the right of each cylinder wall, the six ports being in communication through the passage *u* surrounded by water and kept hot thereby, with the inlet to which the carbureter is bolted. On the left side of each cylinder, opposite the inlet port *t*, there is another opening *v*, known as an exhaust port, that opens into the exhaust manifold *w*.

40. Each sleeve has two ports cut into its upper end, the ports of each sleeve being approximately opposite. The ports *x* on the right side of the inner and outer sleeves serve as ports for the admission of the fresh charge through coming into register with the inlet ports *t* of the cylinders. At the left side of both the inner and the outer sleeve there is a port *y*, and these ports, by coming into register with the exhaust port of the cylinder, serve for the exhaust of the burnt gases.

A number of oil grooves *z* are cut into the outside of each sleeve, and retain the oil supplied by the lubrication system. A number of small holes are drilled through each sleeve, to permit surplus oil supplied to the sleeves to drain back to the crank-case.

Lubrication of the Willys-Knight engine is effected by oil under pressure, which is pumped to the crank-shaft main bearings and thence passes into the hollow crank-shaft and through drilled holes to the crankpins. The surplus oil thrown off in a dense mist from all the crank-shaft bearings lubricates the cylinders, sleeves, pistons, etc. The pressure in the oiling system is shown on a gauge placed on the instrument board of the dash.

41. Before considering the operation of the sleeves of a Knight engine, it must be borne in mind that the designer has considerable latitude in choosing the time at which the inlet and exhaust ports open and close, just as is the case with poppet-valve engines. Thus, in the Willys-Knight six-cylinder engine the exhaust closes 5° after the top dead center is passed, and the inlet opens 25° after the top dead center is passed. The inlet closes 40° after the bottom dead center is passed, and the exhaust opens 45° before the bottom dead center is reached. In a different Knight engine, however, the intake opens on the top dead center of the crank, and closes on the compression stroke when the crank has moved 50° past the bottom dead center; the exhaust opens on the explosion stroke 60° before the crank reaches the bottom dead center, and closes on the suction stroke when the crank is 15° past the top dead center.

42. In studying the action of the sleeves, reference is made particularly to the Willys-Knight six, in which, as stated before, the inlet opens after the top dead center is passed and the inlet closes after the bottom dead center is passed; the exhaust opens before the bottom dead center is reached and closes after the top dead center is passed.

In studying the manner in which the sleeves, through their ports and their movements, control the admission of the fresh charge and the exhaust of the burnt gases, it should be borne in mind that the eccentric shaft turns in the same direction as the crank-shaft and at one-half the speed of the latter; that is, the eccentric shaft makes one revolution for every two revolutions of the crank-shaft. On the eccentric shaft, the crankpins that drive the sleeves are so set that the crankpin driving the inner sleeve is 60° in advance of the one driving the outer sleeve; furthermore, the crankpin driving the inner sleeve is so placed in reference to the engine crank-shaft crankpin that it is practically on the top dead center when the crank-shaft crankpin is on the top dead center and at the beginning of the explosion stroke.

43. Since the sleeve movements are identical in all cylinders, a study of their movements in one cylinder will be sufficient. The events taking place during a complete cycle, or four strokes of the piston, will be explained by the aid of Figs. 30 to 36, which show one of the cylinders of a Knight engine and its sleeves in sections, as they will appear to an observer sitting in the driver's seat and looking toward the radiator; hence, the crank-shaft and eccentric shaft turn in a direction opposite to that of the hands of a watch, or in the direction of the arrows. The same parts are marked with the same reference letters. The inlet port *a* in the cylinder is at the right, as are also the inlet ports of the sleeves; and the exhaust port *b* of the cylinder is at the left, as are also the exhaust ports of the sleeves. The thickness of the sleeves is somewhat exaggerated in the different views of the engine shown in these illustrations, as, otherwise, the construction might not be entirely clear.

44. In Fig. 30 is shown the positions of the sleeves and the crank immediately after the beginning of the suction stroke. The engine crankpin has moved 25° past its top dead center, and the upper inlet-port edge of the inner sleeve and lower inlet-port edge of the outer sleeve are exactly in line with each other. The inner sleeve is practically stationary for this crank position, and the outer sleeve is moving downwards very

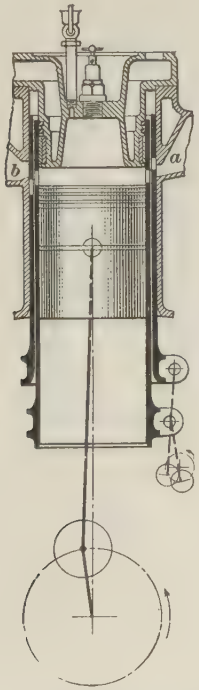


FIG. 30

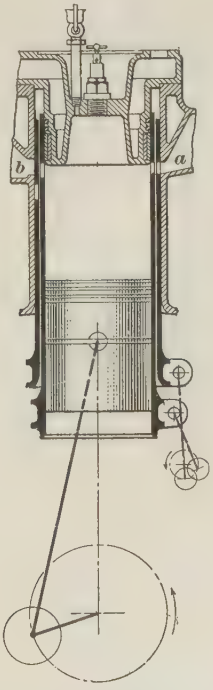


FIG. 31

rapidly. After the engine crank moves a few degrees past the position shown in Fig. 30, the inner sleeve moves upwards and the outer sleeve continues to move downwards, the combination of these two movements bringing the inlet ports of the two sleeves very rapidly into full register with each other and also with the inlet port *a* of the cylinder, thus giving a very quick and large inlet-port opening. The exhaust ports are fully closed.

45. In Fig. 31, the piston and the sleeve are shown in the positions they occupy when the inlet port is wide open. The engine crank has moved to the position shown; the outer sleeve is at the bottom end of its stroke and practically stationary, and the inner sleeve is, as the engine-crank rotation continues, moving upwards at its maximum speed. As the engine

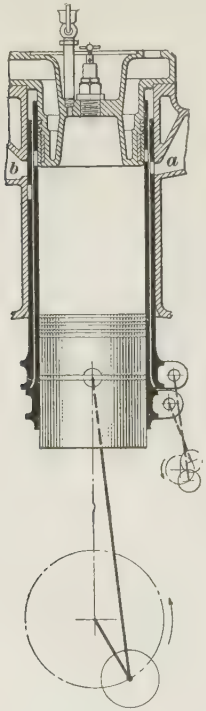


FIG. 32

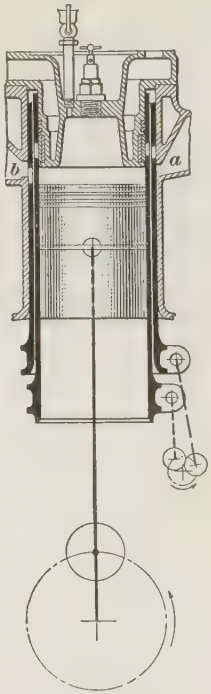


FIG. 33

crank continues to rotate, both sleeves move upwards, the outer sleeves moving very slowly and the inner sleeve very fast; in consequence, the lower inlet-port edge of the inner sleeve overtakes the lower edge of the sealing ring when the engine crank has moved 40° past the bottom dead center. When the two edges referred to are in line, the inlet is closed. The sleeves, piston, and crank are now in the positions shown in Fig. 32, the piston being on its compression stroke. It will be noticed

that the inlet ports of the two sleeves are still slightly in register when the position shown in Fig. 32 is reached, but the intake is sealed by the sealing ring and the inner sleeve.

46. During the continuing rotation of the engine crank from the position shown in Fig. 32, the piston moves upwards and thus compresses the fresh charge; the two sleeves also move upwards, the inner sleeve with a gradually decreasing speed and the outer sleeve at nearly its maximum speed. In Fig. 33 is shown the sleeve positions and the piston position when the engine crank has reached the top center; this is the end of the compression stroke. At this point, the inner sleeve is slightly past the top of its stroke and ready to move downwards, and the outer sleeve is ready to move upwards at a gradually decreasing speed.

47. As the fresh charge has been ignited, the piston, under the influence of the explosion pressure, makes its explosion stroke, the engine crank now having begun its second revolution. When the engine crank has reached the position shown in Fig. 34, where it is 135° from the top center, or 45° from the bottom center, the exhaust port of the outer sleeve is partly in register with the exhaust port in the cylinder, and the lower exhaust-port edge of the inner sleeve, which just now is moving downwards almost at its maximum speed, is just passing the lower edge of the sealing ring. The exhaust is thus opened rapidly as the piston continues its motion.

48. In Fig. 35, the position of the various parts is illustrated at the time the exhaust is wide open; the piston is moving upwards on its exhaust stroke and both sleeves are moving downwards, the inner sleeve at a gradually decreasing speed and the outer sleeve at a gradually increasing speed. By the time the engine crank has moved 5° past the top center, which is the position shown in Fig. 36, the upper exhaust-port edge of the outer sleeve has come in line with the lower edge of the cylinder exhaust port, and the exhaust is closed. The complete cycle of operations is now finished and is ready to be repeated.

49. The control of the inlet and the exhaust may be summarized as follows: The inlet opens because the upper edge of the inlet port of the inner sleeve and lower edge of the inlet port of the outer sleeve pass each other in opposite directions while opposite the cylinder inlet port. The inlet closes because

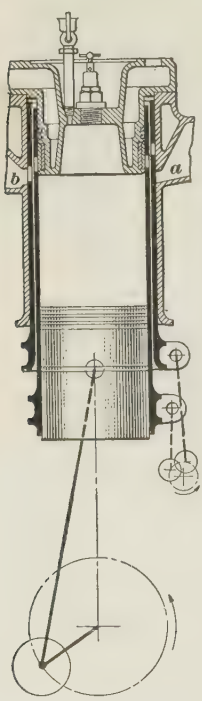


FIG. 34

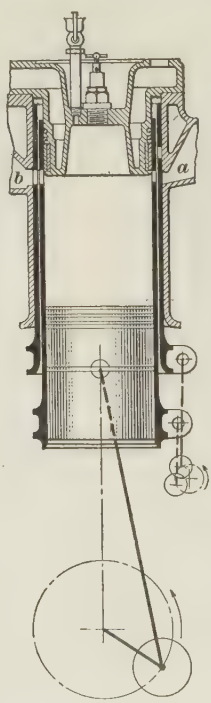


FIG. 35

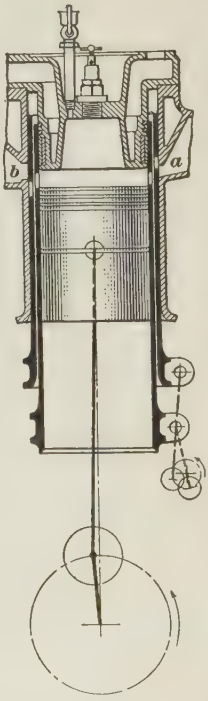


FIG. 36

the lower edge of the inlet port of the inner sleeve moves upwards past the lower edge of the sealing ring. The exhaust opens because the lower exhaust-port edge of the inner sleeve moves downwards past the lower edge of the sealing ring. The exhaust closes because the upper edge of the outer sleeve moves downwards past the lower edge of the cylinder exhaust port.

MISCELLANEOUS ENGINE DATA

PISTON DISPLACEMENT

50. The piston displacement of an engine is the volume of the space through which the piston moves during one stroke. It should be understood, in this connection, that the stroke is the distance that the piston travels in either direction, or, it is the distance that the piston travels while the crank is moving from one dead-center position to the other. The piston displacement can be easily calculated when the internal diameter of the cylinder, known as the bore, and the stroke are known. It is not customary to use the words bore and stroke when designating on paper these dimensions of an engine, the practice being to express them in figures only, as 4×5. When thus given, the first figure, or 4, represents the bore, and the second figure, or 5, the stroke. Thus, a 4×5 engine is one having a 4-inch bore and a 5-inch stroke.

The piston displacement of an engine is equal to the displacement of one cylinder multiplied by the number of cylinders. Expressed as a formula,

$$P=D^2\times.7854\times S\times N$$

in which P = piston displacement, in cubic inches;
D = diameter of the cylinder bore, in inches, and $D^2=D\times D$;
.7854 = a constant;
S = stroke, in inches;
N = number of cylinders in the engine.

Suppose, for example, it is desired to find the piston displacement of a 6-cylinder engine, the dimensions of which are given as 4×5. Then, $D=4$ inches, and $D^2=4\times4=16$ square inches; $S=5$ inches; and $N=6$. Substituting these values in the formula, the piston displacement, or

$$P=16\times.7854\times5\times6=376.99,$$ or 377 cubic inches.

ENGINE SPEED

51. It is often of advantage to know the speed of the engine corresponding to different car speeds, and this can be calculated by the following formula:

$$R.P.M. = \frac{R \times S}{D \times .002975}$$

in which $R.P.M.$ = revolutions per minute of the engine;
R = gear ratio, or the ratio between the speed of the engine and the rear wheels;
S = speed at which car is traveling in miles per hour;
D = outside diameter, in inches, of rear wheels;
.002975 = a constant.

Suppose, for example, it is desired to determine the speed of the engine of a car having a gear ratio of 4 to 1, rear wheels 32 inches in diameter, and traveling 30 miles per hour. Then $R = 4$; $S = 30$; and $D = 32$. Substituting these values in the formula, the engine speed, or

$$R.P.M. = \frac{4 \times 30}{32 \times .002975} = \frac{120}{.0952}$$
$$= 1260.5 \text{ revolutions per minute.}$$

HORSEPOWER RATING

52. Gasoline automobiles are rated in the United States according to the horsepower of the engine. This horsepower is calculated by means of a formula called the *A. L. A. M. formula* and also the *S. A. E. formula,* which is so named because it was adopted by the Association of Licensed Automobile Manufacturers and afterwards by the Society of Automotive Engineers for calculating the rated horsepower of a four-cycle gasoline automobile engine. The formula does not give the exact power delivered under every condition nor the exact theoretical power, but it offers a means of comparison between different engines.

The A. L. A. M., or S. A. E., formula was derived by substituting values that were considered average for an automobile engine in a formula used for determining the horsepower of a steam engine. In this formula,

$$I.\ H.\ P. = \frac{p\ l\ a\ n}{33{,}000}$$

in which $I.\ H.P.$ = indicated horsepower;
p = average pressure on the piston in pounds per square inch;
l = length of piston stroke in feet;
a = area of cylinder bore, or $D^2 \times .7854$;
n = number of strokes per minute;
33,000 = unit of horsepower.

It should be understood that this formula applies to a one-cylinder steam engine, in which every stroke is a working stroke. In order to make it apply to a four-cycle automobile engine, it is necessary to multiply the result by the number of cylinders in the engine, and divide by 4, since only one stroke in every four is a working stroke. As applied to a four-cycle automobile engine, the formula thus becomes

$$H.\ P. = \frac{p\ l\ a\ n \times N}{33{,}000 \times 4}$$

N being the number of cylinders.

In applying this formula to the automobile engine it was assumed that the piston speed, or $n \times l$, of the average engine was 1,000 feet per minute; that the average pressure, or p, was 90 pounds per square inch; and that the mechanical efficiency was 75 per cent. The mechanical efficiency of an engine is the actual power that it is capable of transmitting as compared to the power that it develops theoretically. Substituting these values in the formula given above,

$$H.\ P. = \frac{90 \times D^2 \times .7854 \times 1{,}000 \times .75 \times N}{33{,}000 \times 4}$$

from which $$H.\ P. = .4D^2 \times N$$

or $$H.\ P. = \frac{D^2 \times N}{2.5}$$

in which $H.P.$ = S. A. E. horsepower rating;
D = cylinder diameter, in inches;
N = number of cylinders.

Expressed as a rule, the formula becomes:

Rule.—*The horsepower of a four-cycle gasoline automobile engine is equal to the diameter of the cylinder, in inches, multiplied by itself and by the number of cylinders, and the product divided by 2.5.*

EXAMPLE.—What is the rated horsepower of a four-cylinder four-cycle engine having a cylinder bore of 5 inches?

SOLUTION.—By applying the rule and substituting values,

$$\text{Horsepower} = \frac{5 \times 5 \times 4}{2.5} = \frac{25 \times 4}{2.5} = \frac{100}{2.5} = 40. \quad \text{Ans.}$$

53. Modern engines as a rule have a piston speed greatly in excess of 1,000 feet per minute, and the result obtained by the formula can be made to approach more nearly the actual power developed by the engine, by computing the piston speed of the engine and then multiplying the horsepower value derived from the formula by the ratio between the actual piston speed and the assumed piston speed. To illustrate, it will be assumed that the engine mentioned in the foregoing horsepower example runs normally at a speed of about 2,400 revolutions per minute, and has a $5\frac{1}{2}$-inch stroke. The piston speed of any engine is equal to the number of feet that the piston moves during one revolution, multiplied by the number of revolutions per minute. In the engine in question, the piston will move $5\frac{1}{2}$ inches in each direction, or 11 inches during one revolution. Since 11 inches equal $\frac{1}{1\frac{1}{2}}$ of a foot, the piston speed will be equal to $2{,}400 \times \frac{1}{1\frac{1}{2}} = 2{,}200$ feet per minute. The horsepower, or 40, obtained from the formula, should then be multiplied by $\frac{2{,}200}{1{,}000}$, or 2.2, which gives, as a result, 88 horsepower, which is very much closer to the actual horsepower developed than that indicated by the formula.

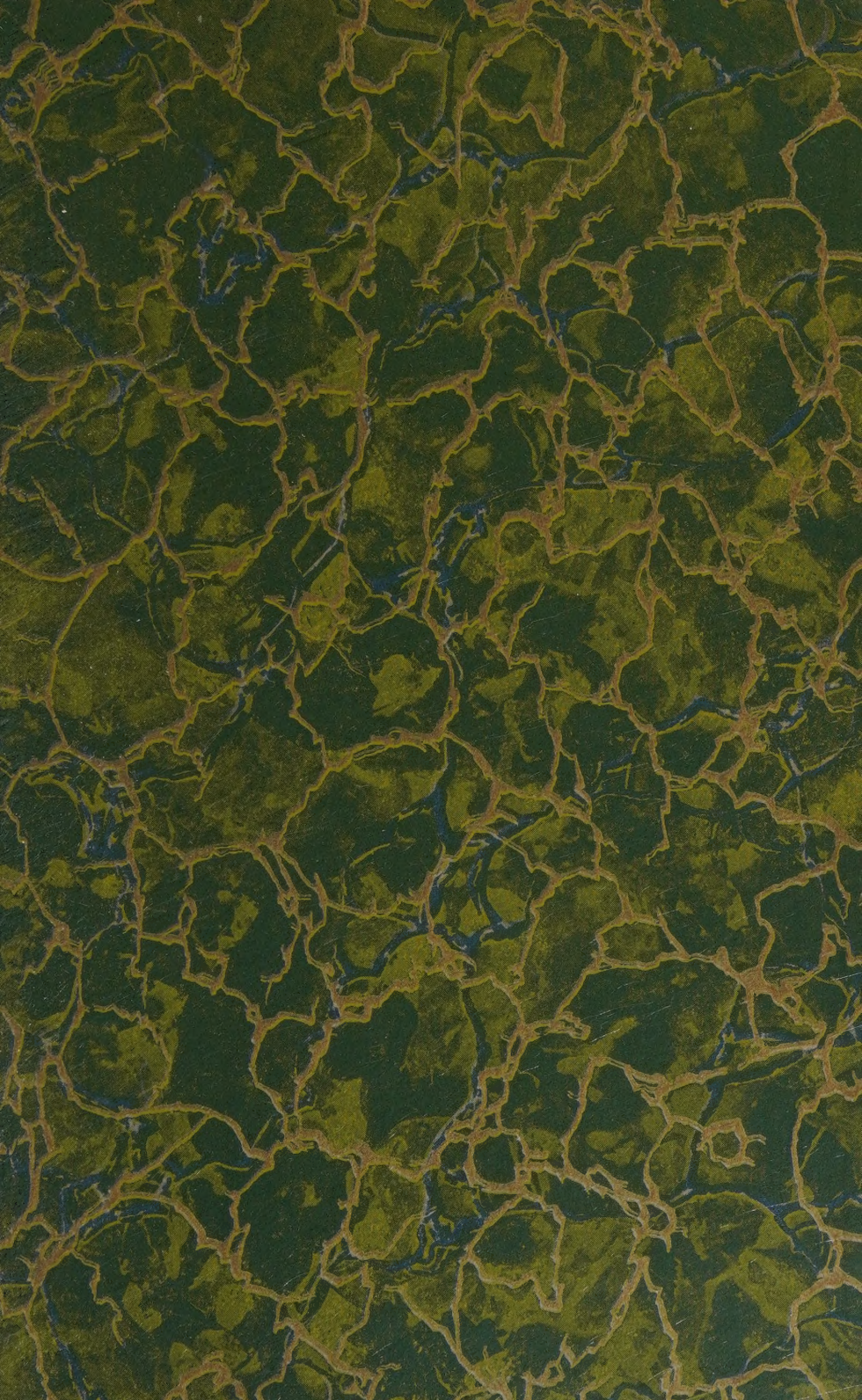
54. The horsepower of four-cycle engines having from one to twelve cylinders and a bore varying from $2\frac{1}{2}$ inches to 6 inches, as computed by the S. A. E. formula, is given in Table I.

TABLE I

HORSEPOWER BY S. A. E. FORMULA

Bore		Horsepower					
Inches	Millimeters	One Cylinder	Two Cylinders	Four Cylinders	Six Cylinders	Eight Cylinders	Twelve Cylinders
2½	63.5	2.50	5.00	10.00	15.00	20.00	30.00
2⅝	66.7	2.76	5.51	11.02	16.54	22.05	33.08
2¾	69.9	3.03	6.05	12.10	18.15	24.20	36.30
2⅞	73.0	3.31	6.61	13.23	19.84	26.45	39.68
3	76.2	3.60	7.20	14.40	21.60	28.80	43.20
3⅛	79.4	3.91	7.81	15.63	23.44	31.25	46.88
3¼	82.6	4.23	8.45	16.90	25.35	33.80	50.70
3⅜	85.7	4.56	9.11	18.23	27.34	36.45	54.68
3½	88.9	4.90	9.80	19.60	29.40	39.20	58.80
3⅝	92.1	5.26	10.51	21.03	31.54	42.05	63.08
3¾	95.3	5.63	11.25	22.50	33.75	45.00	67.50
3⅞	98.4	6.01	12.01	24.03	36.04	48.05	72.08
4	101.6	6.40	12.80	25.60	38.40	51.20	76.80
4⅛	104.8	6.81	13.61	27.23	40.84	54.45	81.68
4¼	108.0	7.23	14.45	28.90	43.35	57.80	86.70
4⅜	111.1	7.66	15.31	30.63	45.94	61.25	91.88
4½	114.3	8.10	16.20	32.40	48.60	64.80	97.20
4⅝	117.5	8.56	17.11	34.23	51.34	68.45	102.68
4¾	120.7	9.03	18.05	36.10	54.15	72.20	108.30
4⅞	123.8	9.51	19.01	38.03	57.04	76.05	114.08
5	127.0	10.00	20.00	40.00	60.00	80.00	120.00
5⅛	130.2	10.51	21.01	42.03	63.04	84.05	126.08
5¼	133.4	11.03	22.05	44.10	66.15	88.20	132.30
5⅜	136.5	11.56	23.11	46.23	69.34	92.45	138.68
5½	139.7	12.10	24.20	48.40	72.60	96.80	145.20
5⅝	142.9	12.66	25.31	50.63	75.94	101.25	151.88
5¾	146.1	13.23	26.45	52.90	79.35	105.80	158.70
5⅞	149.2	13.81	27.61	55.23	82.84	110.45	165.68
6	152.4	14.40	28.80	57.60	86.40	115.20	172.80

To use the table, follow the left column "Bore" downwards until the cylinder diameter is reached. Then pass to the right until the column headed with the number of cylinders in the engine is reached. The value there given is the S. A. E. horsepower. Thus, if the cylinder diameter is $2\frac{7}{8}$ inches and the engine has eight cylinders, the S. A. E. horsepower, by the table, is 26.45.

In the first column on the left under the general heading of "Bore" the cylinder diameter is given in inches and fractional parts of an inch. In the second column under the same heading the cylinder diameter is given in millimeters and decimal parts of a millimeter.

The millimeter is the $\frac{1}{1000}$ part of the meter, which is a unit of length of the metric system of measurement, developed in the eighteenth century in France, and now used in many countries. The meter has a length of approximately 39.37 inches; consequently, the millimeter has a length of .03937 inch, and there are 25.4 millimeters in 1 inch.